HELSINKI UNIVERSITY OF TECHNOLOGY
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SCENARIOS AND SYSTEM DYNAMICS OF MOBILE PEER-TO-PEER CONTENT DISTRIBUTION

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology.

Espoo, March 24th, 2009

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HELSINKI UNIVERSITY OF TECHNOLOGY

Abstract of the Master's Thesis

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Name of the Thesis:	Scenarios and system dynamics of mobile peer-to-peer content distribution		
Date:	24.03.2009	**Number of pages:**	9+84
Department:	Department of Communications and Networking		
Professorship:	S-38 Networking Technology		
Supervisor:	Prof. Heikki Hämmäinen		
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The success of peer-to-peer technology in the fixed networks has led to peer-to-peer implementations in the mobile networks as well. There is, however, a lot of uncertainty regarding the future of mobile peer-to-peer technology as the operators and other stakeholders that were affected negatively by illegal peer-to-peer file sharing in the fixed networks are afraid that it might happen in the mobile domain as well. Thus they might try to prevent mobile peer-to-peer technology from emerging. There is also the question whether there really is a need for peer-to-peer technology in the mobile domain from the end users' perspective, especially as the mobile device capabilities are considerably lower compared to the fixed ones.

This thesis concentrates on mobile peer-to-peer content distribution. Content distribution is divided to file exchange, content streaming and commercial content systems. The thesis provides insight to the most relevant scenarios, stakeholders and their incentives related to mobile peer-to-peer content distribution. The uncertainty regarding mobile peer-to-peer content distribution will be bounded using scenario analysis and modeled using system dynamics. The most relevant scenarios regarding mobile peer-to-peer content distribution are constructed using Schoemaker's method and modeling of these scenarios is attempted with system dynamics. As a result four different scenarios are developed based on the key trends and uncertainties discovered during the literature review and brainstorming sessions. Instead of modeling the scenarios quantitatively, the dynamic behavior of a mobile peer-to-peer content distribution system based on the scenarios is modeled with system dynamics.

Although there are some mobile peer-to-peer content distribution applications already developed and used, and the topic is considerably researched, it is still uncertain what the outcome of the technology will be. This thesis presents possible outcomes for the technology and provides a starting point for further quantitative modeling of mobile peer-to-peer content distribution systems. System dynamics provides a viable alternative to more common modeling techniques such as spreadsheet modeling, with a distinctive benefit of modeling the feedback loops in a system when used proficiently. As the mobile peer-to-peer technology evolves, more data becomes available and the construction of alternative system dynamics models is encouraged.

Keywords: Mobile Peer-to-Peer, Content distribution, Scenario analysis, System Dynamics

TEKNILLINEN KORKEAKOULU

Diplomityön tiivistelmä

Tekijä:	Juuso Olli Aleksi Karikoski		
Työn nimi:	Mobiilin vertaisverkon sisällönjakelun skenaariot ja systeemidynamiikka		
Päivämäärä:	24.03.2009	**Sivumäärä:**	9+84
Laitos:	Tietoliikenne- ja tietoverkkotekniikan laitos		
Professuuri:	S-38 Tietoverkkotekniikka		
Työn valvoja:	Prof. Heikki Hämmäinen		
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Vertaisverkkoteknologian menestys kiinteissä verkoissa on johtanut vertaisverkkototeutuksiin myös mobiileissa verkoissa. Mobiilin vertaisverkkoteknologian tulevaisuuden suhteen on tosin vielä paljon epävarmuutta, koska operaattorit ja muut sidosryhmän jäsenet, jotka kärsivät laittoman tiedostonvaihdon seurauksista kiinteän verkon puolella, pelkäävät saman tapahtuvan myös mobiileissa verkoissa. Täten he saattavat yrittää estää mobiilin vertaisverkkoteknologian kehittymistä. On myös epävarmaa onko mobiilille vertaisverkkoteknologialle tarvetta loppukäyttäjän näkökulmasta, eritoten kun mobiililaitteiden suorituskyvyt ovat huomattavasti alhaisempia kuin kiinteiden.

Tämä diplomityö keskittyy mobiilin vertaisverkon sisällönjakeluun. Sisällönjakelu on jaettu tiedostonvaihtoon, sisällön suoratoistoon ja kaupallisiin sisältöjärjestelmiin. Työ antaa näkemystä mobiilin vertaisverkon sisällönjakelun olennaisimpiin skenaarioihin, sidosryhmän jäseniin ja heidän kannustimiin. Mobiilin vertaisverkon sisällönjakelun epävarmuutta rajataan käyttämällä skenaarioanalyysiä ja mallinnetaan systeemidynamiikalla. Olennaisimmat skenaariot rakennetaan Schoemakerin metodilla ja niiden mallinnusta yritetään systeemidynamiikan keinoin. Tuloksena saadaan neljä eri skenaariota, jotka on kehitetty ”brainstorming”-tilaisuuksissa ja kirjallisuuskatsauksessa löydettyjen avaintrendien ja -epävarmuustekijöiden perusteella. Skenaarioiden kvantitatiivisen mallinnuksen sijaan mallinnetaan skenaarioihin perustuvan mobiilin vertaisverkon sisällönjakelujärjestelmän dynaamista käyttäytymistä.

Vaikka joitakin mobiilia vertaisverkkoteknologiaa hyödyntäviä sovelluksia on jo kehitetty ja käytössä, sekä aihetta tutkittu laajasti, vieläkin on epävarmaa mikä teknologian vaikutus tulee olemaan. Tämä diplomityö esittää mahdollisia vaikutuksia teknologialle ja antaa lähtökohdan tulevalle mobiilien vertaisverkon sisällönjakelujärjestelmien kvantitatiiviselle mallinnukselle. Systeemidynamiikka on toteuttamiskelpoinen vaihtoehto tavallisemmille mallinnustekniikoille, kuten taulukkolaskentamallinnukselle, jonka etuna on järjestelmän takaisinkytkentäsilmukkojen mallintaminen. Kun mobiili vertaisverkkoteknologia kehittyy, enemmän dataa tulee saataville ja vaihtoehtoisten systeemidynamiikkamallien rakentaminen on suositeltavaa.

Avainsanat: Mobiili vertaisverkko, sisällönjakelu, skenaarioanalyysi, systeemidynamiikka

Preface

This Master's Thesis has been written as a partial fulfillment for the Master of Science degree in Helsinki University of Technology. The work was carried out at the Department of Communications and Networking at the Helsinki University of Technology as a part of the DECICOM[1] project and Econ@Tel[2] context.

At first I wish to thank Professor Heikki Hämmäinen for giving me the opportunity to work in his team and write the thesis under his guidance. A word of thanks to Mikko Heikkinen also, who was the instructor of my thesis and gave me a lot of feedback and support throughout the research process.

I wish also to thank the whole Networking Business –team of the department for participation in the Brainstorming session and discussions regarding my work. I especially wish to thank my colleagues from room F301, Antero Kivi, Antti Riikonen and Timo Smura for creating a lively working atmosphere.

Last but not the least I want to thank my parents, Jukka and Anne, for supporting me during my studies.

Espoo, March 24th, 2009

Juuso Karikoski

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[1] DECICOM (Decentralized Inter-Service Communications) is a national research project in 2007-2010 funded by Finnish Funding Agency for Technology and Innovation (TEKES), Nokia, Ericsson, Nethawk, Futurice and Icecom.

[2] Econ@Tel (A Telecommunications Economics COST Network, COST605) is a European research network consisting of research units in 20 countries.

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Abbreviations

3G	Third Generation
3GPP	3rd Generation Partnership Project
4G	Fourth Generation
AoR	Address of Records
BTEN	BitTorrent Entertainment Network
C2C	Consumer-to-Consumer
CDMA	Code Division Multiple Access
CPU	Central Processing Unit
C-S	Client-Server
CSIM	CDMA Subscriber Identify Module
DCIA	Distributed Computing Industry Association
DHT	Distributed Hash Table
DRM	Digital Rights Management
GPRS	Global Packet Radio Service
GSM	Global System for Mobile Communications
HSPA	High-Speed Packet Access
HUT	Helsinki University of Technology
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPR	Intellectual Property Rights
IPTV	Internet Protocol Television
IRC	Internet Relay Chat
ISP	Internet Service Provider
MANET	Mobile Ad Hoc Network
MAP	Mobile Ad Hoc Peer-to-Peer
MMS	Multimedia Messaging Service
MOVi	Mobile Opportunistic Video-on-Demand
MP2P	Mobile Peer-to-Peer

MVNO	Mobile Virtual Network Operator
MWS	Mobile Web Server
NAT	Network Address Translation
NRC	Nokia Research Center
OMA	Open Mobile Alliance
P2P	Peer-to-Peer
P2PSIP	Peer-to-Peer Session Initiation Protocol
P2PTV	Peer-to-Peer Television
P4P	Proactive Network Provider Participation for P2P
PC	Personal Computer
PDA	Personal Digital Assistant
R-UIM	Removable User Identity Module
SCWS	Smart Card Web Server
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
TTL	Time to Live
UICC	Universal Integrated Circuit Card
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
USIM	Universal Subscriber Identity Module
VoD	Video on Demand
VoIP	Voice over IP
VPN	Virtual Private Network
WLAN	Wireless Local Area Network
WWRF	Wireless World Research Forum

1 Introduction

This chapter gives insight to the background of the research. The research questions, objectives, scope and methods are presented and the chapter finishes with an outline of the thesis structure.

1.1 Background of the research

In recent years peer-to-peer (P2P) technology has gained more and more attention mainly because of the illegal file sharing that happens in P2P networks. The popularity of P2P is based on the free sharing of digital content directly between users and is further reinforced because of the ever increasing device capabilities and network connections that make the content distribution faster.

Now this trend is moving towards the mobile domain as the wireless connection speeds and mobile device capabilities are increasing as well. Mobile peer-to-peer (MP2P) as a technology, however, is still only at the outset and the future outcomes that it might have are uncertain. In spite of the success P2P has achieved in the fixed domain, there are no guarantees that P2P will succeed in the mobile domain as well. The stakeholders that were negatively impacted by P2P file sharing in fixed networks might try to prevent this from happening in the mobile domain and it is also unclear whether there is a need for MP2P from the users' perspective just to give a few examples. At the moment MP2P technologies and applications are being researched heavily. Some applications have already been developed and made publicly available, but the actual usage of MP2P is still small.

In this thesis scenario analysis and system dynamics are used to bound the uncertainty related to the future and study the dynamic behavior of MP2P content distribution. By means of scenario analysis, different alternative futures, i.e. scenarios of MP2P content distribution are built, and modeling of these scenarios is attempted with system dynamics.

1.2 Research questions

There are two main research questions in this thesis from which the first one is further divided to four sub questions.

1. What are the most important scenarios for MP2P content distribution?

> *a. Which stakeholders are involved in the scenarios?*
> *b. Why are they involved in the scenarios?*
> *c. How are the stakeholders interrelated in each scenario?*
> *d. How do the scenarios differ from each other?*

2. How to turn the scenarios into relevant system dynamic models?

1.3 Objectives of the research

This thesis has two main objectives - understanding the most relevant scenarios, stakeholders and their incentives related to mobile peer-to-peer content distribution and building a system dynamic model based on the scenarios.

1.4 Scope of the research

The research in this thesis will be limited to MP2P content distribution in the Finnish mobile industry and markets during the time span of 2009-2013. Because of the ambiguous concepts of P2P and mobility, they will be defined and limited as well.

There are several definitions for P2P in literature and a definition which is commonly agreed upon cannot be found. In this thesis the definition is adapted from Androutsellis-Theotokis and Spinellis (2004), where P2P systems are defined as *'distributed systems consisting of interconnected nodes able to self organize into network topologies with the purpose of sharing resources such as content, CPU cycles, storage and bandwidth, capable of adapting to failures and accommodating transient populations of nodes while maintaining acceptable connectivity and performance, without requiring the intermediation or support of a global centralized server or authority'*.

Mobile as a term is imprecise as well and thus it has to be defined. Because of the limited research conducted in the area of MP2P and cellular phones or other personal small-scale devices, also laptop computers are considered as mobile devices in this thesis. Thus the definition of a mobile device is as follows: '*Mobile devices are personal portable laptop computers and personal portable pocket-size computing devices such as advanced cellular phones, personal digital assistants (PDA) and tablet computers that have a cellular or a wireless access to Internet or an operator network*'.

1.5 Research methods

The research methods of this thesis include a literature study, brainstorming, scenario analysis, and system dynamics.

A **literature study** is used to gain an understanding of the underlying technologies and to review the previous and recent research conducted in the area of MP2P content distribution.

Brainstorming is used to gain a more objective viewpoint of the trends and uncertainties associated with the future of MP2P content distribution. This viewpoint is used together with the author's subjective views to construct the most relevant scenarios using Schoemaker's (Schoemaker, 1993) method as the **scenario analysis** method.

The modeling of the dynamic behavior of the scenarios is performed using **system dynamics**, which is a system engineering method used widely across different disciplines in modeling complex systems.

1.6 Structure of the thesis

This thesis follows a traditional thesis structure. After the first introductory chapter the literature study and background research are presented in chapter 2. Chapter 3 introduces the research methods. The author's own contribution begins with chapter 4 where the most relevant scenarios are constructed and then a system dynamics model built based on them. Chapter 5 presents the conclusions of the thesis, including the results, analysis and discussion, and further research.

2 Background research

This chapter serves as the literature study of this thesis. The concept of P2P will be introduced together with the stakeholders and their incentives in MP2P. The idea of content distribution and related scenario work in the area of MP2P will also be presented.

2.1 Peer-to-peer

P2P is a paradigm for communication which offers an alternative to the basic client-server model used widely in Internet. The roles of client and server are mixed so that each peer operates as a server and a client simultaneously, downloading uploading and routing data. The term peer refers to the combined entity of a user and the computer or device used by the user for accessing the network. These peers can also be called *Servents* (SERVers+clieENTS) (Schollmeier, 2001). P2P can be seen as the interaction between users as well, but in this thesis the focus is on the technical aspect.

Systems based on P2P are primarily of decentralized nature both in resource usage and self-organization. The purpose of a P2P system is to share resources, such as content, bandwidth, storage space and processor cycles and to be able to organize the possibly transiently interconnected nodes to a network topology by itself. All of this should happen without the intermediation of a global centralized authority while maintaining connectivity and performance (Androutsellis-Theotokis and Spinellis, 2004). All the peers in a P2P networks contribute to the overall resources of the system in terms of e.g. bandwidth and computing power and thus the overall capacity of the system increases as more peers join the network. The robustness of the system also increases because of the distributed nature of P2P because data is replicated over multiple peers. Although the client-server based applications have become and still are popular since the beginning of 1980s, nowadays more than 50% of the Internet traffic is caused by P2P applications (Steinmetz and Wehrle, 2005). Azzouna and Guillemin (2004) claim that it can be almost 80%. P4P (Proactive Network Provider Participation for P2P) is a recent attempt by the DCIA (Distributed Computing Industry Association) P4P Working Group to optimize P2P traffic by enabling explicit communications between P2P applications and network providers (Xie et al., 2008).

In P2P applications *Free-Riding* is a common problem. Free-Riding means that some users do not contribute to the P2P network by sharing resources and only consume them. In addition, the minority of users share the majority of resources as measured by Saroiu et al. (2002). Another issue in P2P is the effect of *Long Tail*. The Long Tail means that the majority of the files in a P2P network have been duplicated only a few times, whereas the most popular files may have been duplicated hundreds of times (Raivio, 2005).

2.1.1 Overlay networks

Clark et al. (2006) discuss overlay networks and the future of the Internet. P2P networks are overlay networks which means that they are formed independently on top of the underlying physical computer network (Figure 1). This underlying network is usually based on the Internet Protocol (IP) and is also considered to be based on IP in the scope of this thesis. Nodes in the overlay are connected through virtual or logical links, which can consist of many physical links in the underlying network. In an overlay network every peer knows the location of at least one other peer and the links are managed by a protocol that uses some specific algorithm. The different overlay networks can be distinguished in terms of their architecture and structure as discussed in the following subchapters.

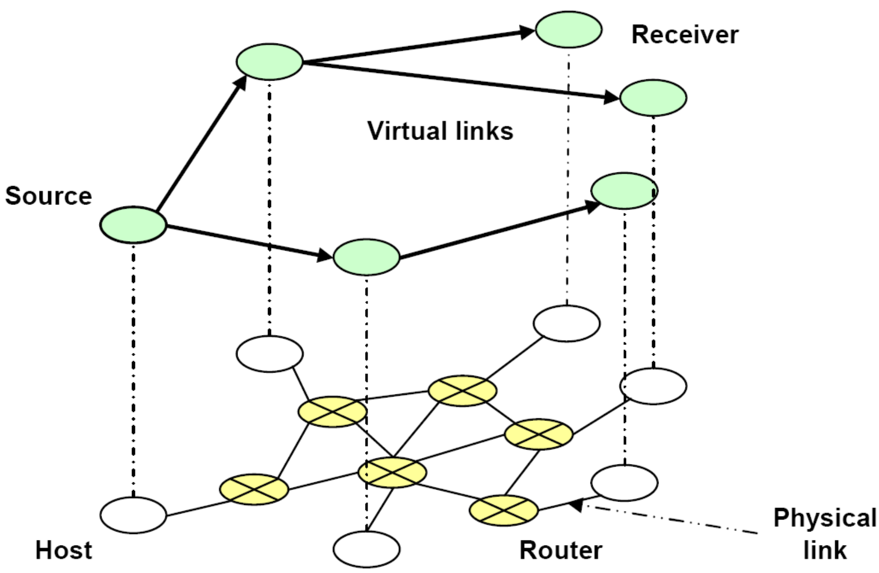

Figure 1: Overlay network

2.1.2 Network architecture

The P2P network architecture can be divided to three main classes namely the *pure*, *centralized* and *semi-centralized* architectures.

As the name implies the *pure* architecture (Figure 2) is P2P at its purest – no central entities are controlling the system, search and data download processes are distributed and all nodes are equal in terms of functionality and tasks. An example of a pure architecture is *Gnutella*[3] which uses Time to Live (TTL) limited flooding to locate resources.

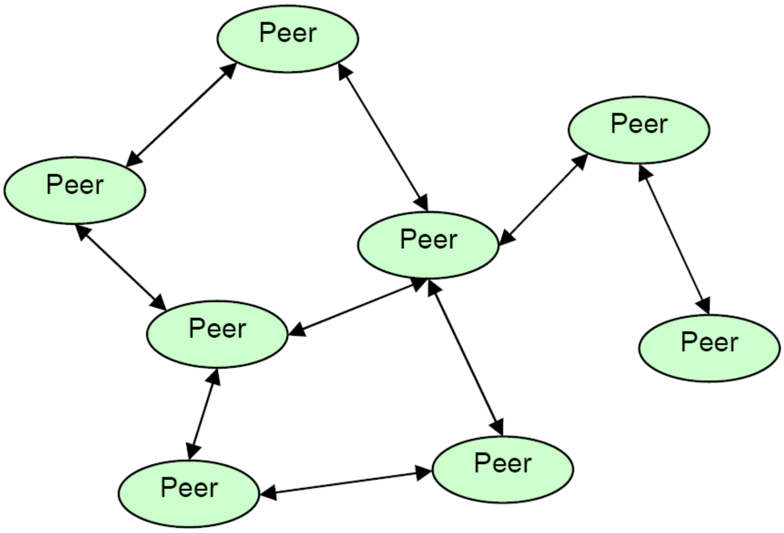

Figure 2: Pure P2P architecture

In the *centralized* architecture (Figure 3) a central entity controls the network i.e. keeps all the information of the peers participating in the network, including for example their presence information and willingness to share content. The drawback of centralized architectures is that they have a single point of failure which results in unscalability and vulnerability to censorship, technical failure, or malicious attack. *Napster*[4] was an example of a centralized P2P architecture and failed because of its central server which maintained the current locations of data items.

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[3] http://www.gnutelliums.com/ [Accessed 27.11.2008]

[4] http://free.napster.com/ [Accessed 27.11.2008]

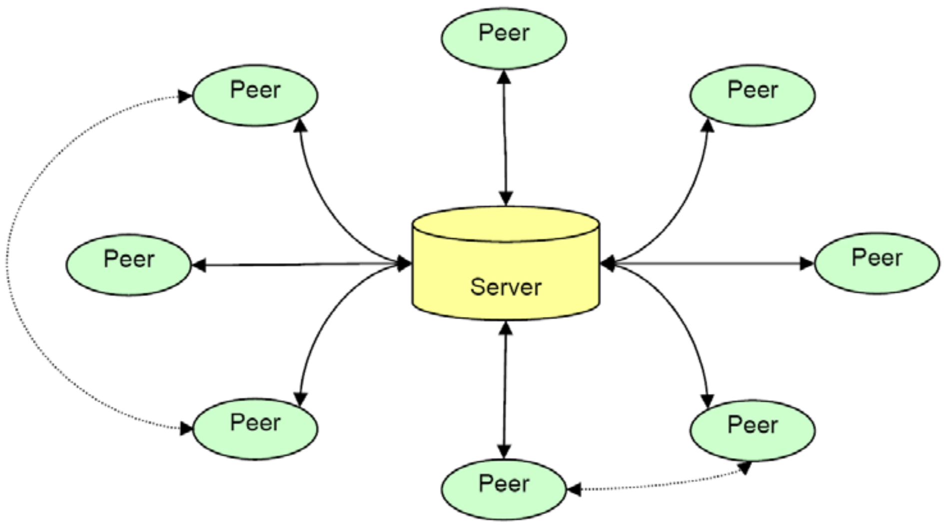


Figure 3: Centralized P2P architecture

The *semi-centralized* or *hybrid* (Figure 4) architecture combines both the pure and the centralized architectures by maintaining the scalability while having some control of the network. This is usually accomplished with superpeers that are more capable than normal peers and function as stable server-like peers. Superpeers reduce the discovery time in comparison to pure systems and there is no single point of failure. The heterogeneity of the peers can also be exploited by assigning the more capable peers as superpeers while the normal peers remain lightly loaded. The assignment of superpeers depends on the system but basically superpeers are dynamically assigned and automatically elected so that a failure of a superpeer does not bring the whole system down. Superpeers index the files from peers that are connected to them and all queries are initially directed to superpeers. *KaZaA* is an example of a hybrid P2P system (Matuszewski et al., 2006; Androutsellis-Theotokis and Spinellis, 2004).

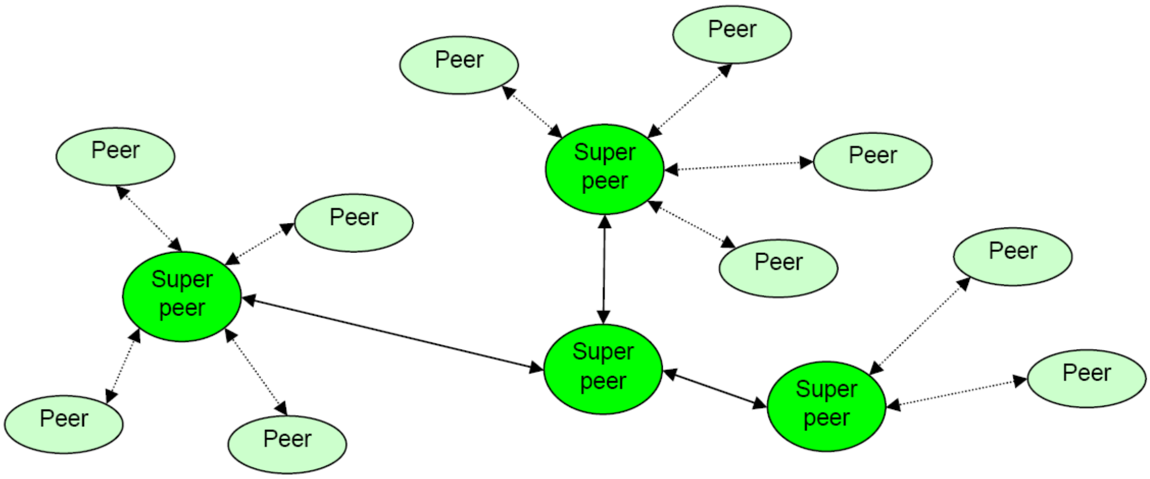


Figure 4: Hybrid P2P architecture

2.1.3 Network structure

The P2P systems can also be categorized according to their structure i.e. whether the overlay network is constructed non-deterministically or based on specific rules. In an *unstructured* P2P system the placement of content is completely unrelated to the overlay network i.e. the IP address of a node and the content stored in it are unrelated and do not follow any specific structure (Androutsellis-Theotokis and Spinellis, 2004). In unstructured systems flooding is used for queries and highly replicated items can be found easily. Flooding however is not good for locating rare items and the load on each peer grows linearly with the amount of queries and the system size. Thus in unstructured P2P networks peers become overloaded and the system does not scale well. Different unstructured P2P overlay networks such as *Gnutella* and *KaZaA* are surveyed and compared in (Lua et al., 2005).

In a *structured* system a mapping between the content and the nodes IP address is established and thus the overlay topology is strictly controlled and files are stored at exactly specific locations (Androutsellis-Theotokis and Spinellis, 2004). The mapping is most commonly based on a Distributed Hash Table (DHT) (Steinmetz and Wehrle, 2005), which will be described in the next subchapter. In structured systems the queries are more efficient enabling scalable wide-area retrieval of shared information. However the look-up latency can be quite high in DHT-based P2P overlay networks which can affect the performance of the applications running on top of it. Different structured P2P overlay networks such as *Chord* are surveyed and compared in (Lua et al., 2005).

Also a *loosely structured* network category exists, where the location of content is not entirely specified but affected by routing hints (Androutsellis-Theotokis and Spinellis, 2004). This approach tries to maintain some of the scalability of the structured networks with placement of files based on anonymity. An example of a loosely structured P2P network is *Freenet* (Lua et al., 2005). One should take notice that all structured and also loosely structured systems are inherently of a pure architecture, because form follows function.

Both structured and unstructured systems are complementary and acceptable solutions and the choice depends on the application, required functionalities and performance metrics (Lua et al., 2005). In P2P systems structured networks are more common (Seppänen, 2007). The classification of different P2P protocols can be seen in Figure 5.

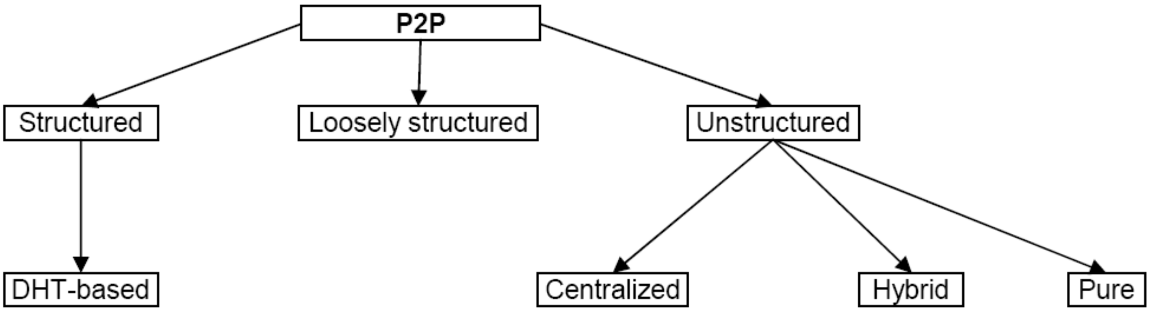
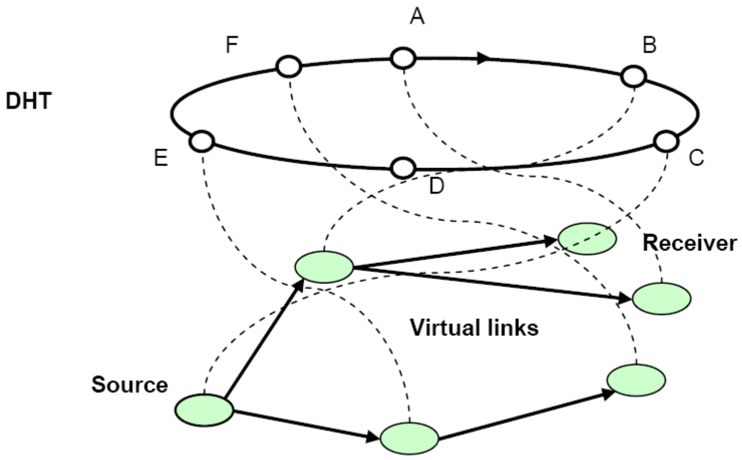


Figure 5: Classification of P2P protocols

Distributed Hash Table (DHT)

DHT is a proactive strategy, where each node becomes responsible for a specific range of data items. Each node has a partial view of the whole network, which effectively distributes the routing information, i.e., the nodes have a limited number of links to other nodes. Each data item is assigned an identifier ID (or a key), which is a unique value from the address space. This way the data item is stored at the node which is responsible for the portion of the address space containing the ID. If a node is not responsible for a message with a given destination ID, it will forward the message to the node that manages the address space containing the IDs numerically closest to the destination ID (Wehrle et al., 2005). As stated above DHT-systems can have a high look-up latency, but on the other hand it can be guaranteed in theory that any data object can be found in *O(logN)* hops on average, where *N* is the amount of nodes in the system (Lua et al., 2005). One of the most widely used DHTs is the *Kademlia* DHT (Maymounkov and Mazieres, 2002) and there is also a recently released implementation of it in the mobile environment called *Mobile Kademlia*[5].

The address space in DHT usually consists of large integer values from zero to $2^m - 1$ (where m is a positive integer value) and the topology is often described as ring-like as in Figure 6.



Node	Address space
A	0 - 682
B	683 - 1364
C	1365 - 2047
D	2048 - 2729
E	2730 - 3412
F	3413 - 4095

Figure 6: DHT with a linear address space of (2^12)-1 integer values

2.1.4 Peer-to-peer generations

The evolution of P2P systems can be divided to different generations. There are different definitions for the P2P generations and the one used in this thesis is adapted from Hughes et al. (2007).

In the first generation of P2P systems e.g. *Napster* and *Limewire*[6] content is searched from a central index server, but the actual data transfer is carried out between peers. Thus the architecture is of a semi-centralized or centralized nature.

The second generation systems abandon the centralized architecture and use distributed file indexing. This way the central server is eliminated but also the reach

[5] http://www.aut.bme.hu/MobileDHT [Accessed 12.11.2008]

[6] http://www.limewire.com/ [Accessed 27.11.2008]

of the system is limited because the queries only reach a portion of the network. Second generation systems are usually powered by the *Gnutella* engine and include e.g. *KaZaA* and *Grokster*[7].

The third generation allows simultaneous downloading from multiple sources as well as simultaneous uploading leading to the possibility of sharing very large files. The most prominent example of the third generation is *BitTorrent*[8].

Fourth generation added the concept of Virtual Private Networks (VPN) to P2P. The P2P file sharing systems can be organized as small VPNs and thus the file-sharers that do not want to share files with large Internet communities can have a network where the access is limited and controlled by membership and passwords. Also businesses that want to exchange in-house documents can use fourth generation P2P systems like the *QNext*[9].

The fifth generation of P2P systems includes e.g. Instant Messaging (IM) and Internet Relay Chat (IRC) and other protocols that were designed for something else than file sharing. This way the users can share files in less visible and harder to track niches of the Internet.

Also other definitions of P2P generations exist. One might think of a generation of anonymous P2P systems where information is routed through several nodes and thus the identification of the downloaders and the senders becomes more difficult. Also P2P streaming might be considered as its own generation as discussed by Sigurdsson et al. (2007).

2.2 Mobile peer-to-peer

Although the P2P paradigm is widely used and extremely popular in fixed Internet it hasn’t yet succeeded that well in the mobile environment. This is mainly because of the limitations that the mobile environment brings along, but as the capabilities of mobile devices grow, P2P is expected to succeed in the mobile environment as well.

[7] http://www.grokster.com/ [Accessed 27.11.2008]

[8] www.bittorrent.com [Accessed 27.11.2008]

[9] www.qnext.com [Accessed 27.11.2008]

The Wireless World Research Forum (WWRF, 2001) envisaged already in 2001 that there will be a paradigm shift from a provider centric paradigm to a decentralized P2P paradigm in fourth generation (4G) wireless networks.

A recent measurement about MP2P usage in Finland has been carried out by Heikkinen et al. (2009). For handsets they noticed almost zero file sharing traffic during 2005-2007, but also 9-18% of unidentified traffic which possibly is P2P traffic. For computers MP2P traffic amounts for 4-5% with up to 60% of unidentified traffic.

2.2.1 Technical constraints and characteristics

As stated above MP2P has many constraints that do not exist in fixed networks (Lehtinen, 2008). First of all there is limited network bandwidth available for the mobile device. This has to be accounted for by minimizing non-relevant traffic like for instance forwarding of unneeded search traffic. The user interface of the mobile device creates some constraints too, mainly because of the limited screen and keyboard size. The bandwidth is often asymmetric which brings its own constraints to P2P because the content is being distributed from the mobile nodes. The mobile devices also have limited computational power both the CPU power and available program memory. The limited battery capacity of mobile devices can be conserved using less bandwidth, less computationally intensive algorithms and small data structures. Because of these constraints free-riding is also more attractive in mobile networks.

There are other issues in addition to the technical issues stated above that characterize mobile environments. First of all the mobile devices are truly heterogeneous and thus there is for example potential for legal conflicts in terms of Intellectual Property because content has to be adapted to each device. Mobile networks usually have a high churn, i.e. they are characterized by frequent joins and leaves of nodes (Kellerer et al., 2005). Thus minimizing the signaling overhead for other nodes becomes even more important as nodes join or leave the network. The radio selection of mobile devices is an issue too, since the devices nowadays have several radios that support packet data. The device should always select the best possible radio for each situation. In MP2P free communication between peers over operator boundaries has to be guaranteed while P2P is also based on openness in general. Thus operator control can be an issue – free communication has to be enabled while having some control over the peers. However some operators like Elisa and DNA in Finland have prohibited or limited MP2P traffic in their mobile broadband services (Elisa, 2008; DNA, 2007).

2.2.2 Network architecture

In the light of the technical constraints stated above one should select a MP2P architecture that creates minimal signaling load, has efficient protocol coding and uses no complex algorithms or large data structures. These kinds of architectures are centralized and semi-centralized or hybrid architectures where the most overhead is placed on the superpeers. However it must be accounted for that there can be major problems in centralized systems in terms of scalability and control placement if millions of users are distributed among various mobile operators, possibly in various countries.

2.2.3 Advantages

MP2P however brings about also a lot of advantages for mobile users. If no infrastructure is available communication can be enabled using MP2P and with hopping technologies overall communication range can be extended by hopping through other peers to reach the destination. Infrastructure costs can also be saved in terms of configuration and maintenance. MP2P can result in reduced traffic because only the content is uploaded which is requested. From the user perspective instant services can be offered directly instead of uploading them to a server and the users feel that they are in control uploading only what they want. With MP2P technology spontaneous ad-hoc groups can be formed, although this can also already be accomplished by existing Mobile Ad Hoc Network (MANET) technology. Searching content only with normal web search engines can be complemented by searching content from your mobile social network as discussed by Tiago et al. (2008). This way the interference of a third entity can be avoided and it is easier to find content which might be personally or socially connected to you.

2.2.4 Access networks

In general there are two subcategories of mobile access networks that MP2P can work on top of, namely cellular networks and MANETs. According to Duran and Shen

(2004) P2P over MANET is also called Mobile Ad-hoc P2P (MAP). The mobile access networks and their most important characteristics are summarized in Table 1.

Cellular networks

There is a variety of cellular networks available, e.g., Global Packet Radio Service[10] (GPRS), Universal Mobile Telecommunications System[11] (UMTS) and High-Speed Packet Access[12] (HSPA) from 3GPP (3rd Generation Partnership Project) to name a few. The integration of these systems is expected when the fourth generation (4G) systems are introduced. In addition to the systems listed above which all are evolved from the second generation GSM[13] (Global System for Mobile Communications) network, there are also short range cellular networks, e.g., Bluetooth and Wireless Local Area Network (WLAN) both standardized by the Institute of Electrical and Electronics Engineers (IEEE, 2005; IEEE, 2007). Bluetooth and WLAN also provide the infrastructure for MANETs as described in the next subchapter.

The idea in cellular networks is that there are only one hop routes from the base station to the node and vice versa and thus the nodes are connected to the fixed Internet with a single wireless link. Even if the node moves it can be stated that the physical path to this node does not change very much. Thus the P2P overlay can be constructed straight on top of the cellular network (Kellerer et al., 2005).

Mobile Ad Hoc Networks

MANETs are wireless self-configuring, multi-hop networks that do not have an infrastructure like the base stations or central databases in cellular networks. The nodes in a MANET are sources, sinks and routers at the same time. This means that the nodes in the physical proximity are used as relays for routing and every node can initiate and receive a data transfer (Kellerer et al., 2005).

In comparison to P2P networks MANETs seem to be quite similar, since the peers have similar responsibilities on the application layer. There are however differences

[10] http://www.3gpp.org/article/gprs-edge [Accessed 27.11.2008]

[11] http://www.3gpp.org/article/umts [Accessed 27.11.2008]

[12] http://www.3gpp.org/HSPA [Accessed 27.11.2008]

[13] http://www.etsi.org/WebSite/Technologies/gsm.aspx [Accessed 27.11.2008]

and the biggest challenge for mobile ad hoc peer-to-peer networks is the instability of the physical network that is caused by the movement of the nodes and the resulting changing connections. In multi-hop networks traffic could be drastically minimized if the peers were aware of the underlying physical network instead of assuming it to be fixed and thus the number of hops of the P2P path could be reduced. In MAP networks the movement of the nodes has to be taken into account, since the physical path between nodes is bound to change from time to time. If the P2P overlay would be constructed totally independently on top of the MANET, the MANET might not be able to sustain the high traffic volumes caused by long and unstable routes. To achieve a workable integration of MANETs and P2P overlays cross-layer communication is needed. Ding and Bhargava (2004) have compared different cross-layer routing protocols in their study and concluded that they indeed offer significant improvement in MAP networks.

Table 1: Mobile access networks and their characteristics

Access Network	Data Rate	Coverage	Frequency Range
Cellular Networks:			
GSM	9,6kbps	Nation-wide	900, 1800 MHz
GPRS	40kbps	Nation-wide	1900 MHz
UMTS	< 384kbps	Partially nation-wide	2 GHz
HSPA	< 14,4 Mbps	Partially nation-wide	2 GHz
Wireless LAN:			
IEEE 802.11a	< 54 Mbps	50-300 m	5 GHz
IEEE 802.11b	< 11 Mbps	50-300 m	2,4 GHz
IEEE 802.11g	< 54 Mbps	50-300 m	2,4 GHz
Wireless PAN:			
Bluetooth	< 1 Mbps	1, 10 or 100 m	2,4 GHz
IrDA	4 Mbps	Line of Sight	Infrared

2.2.5 Mobile peer-to-peer SIP

Since many of the next generation networks will be largely based on established protocols such as the Session Initiation Protocol (SIP), developing a platform for MP2P services on top of those protocols seems reasonable. The adaptation of such a platform is also simpler than of a proprietary platform. This is why many solutions have already been developed such as the hybrid MP2P file-sharing platform by Lehtinen (2008) that uses SIP as its underlying signaling protocol. Also the mobile P2PSIP system implemented by Matuszewski and Kokkonen (2008) that distributes the task of locating SIP proxies, SIP endpoints and other services, and the mobile P2PSIP content sharing system for a cellular network implemented by Matuszewski et al. (2006) are implemented mobile P2PSIP solutions. Mobile P2PSIP communications services have also been analyzed from a scenario analysis perspective by Heikkinen et al. (2008). In this chapter the SIP and P2PSIP protocols are briefly described and also the effects of P2PSIP on mobile operators discussed.

SIP

Session Initiation Protocol is a standardized protocol by the Internet Engineering Task Force (IETF) and it is specified in RFC3261 (Rosenberg et al., 2002). SIP is an application-layer control protocol for establishing, controlling and terminating multimedia sessions, which include e.g. Internet telephony calls, video conferences, Instant Messaging (IM) and gaming sessions. SIP does not provide services; instead it provides the tools for implementing different services. In session establishment SIP is used only as a signaling protocol distributing session descriptions among potential participants. If this is successful, SIP can be used to modify the session and finally terminate the session.

P2PSIP

Bryan et al. (2008) are currently working on a draft about the concepts and terminology of P2PSIP and as the document matures it is expected to define the general framework for P2PSIP. As the name implies the nodes, called peers, in a P2PSIP overlay are organized in a P2P fashion with the purpose of enabling real-time communication using SIP. The location server functionality of SIP is replaced by having a distributed mechanism provided by the nodes for mapping Address of Records (AoR) i.e. the names of the users to overlay locations. SIP messages can be transported between any two nodes in the overlay by means of a transport function.

The distributed database algorithm collectively run by the peers allows the retrieval and storage of data on peers in an efficient manner. One option to realize the algorithm is to use a Distributed Hash Table (Wehrle et al., 2005). The data might also be stored on several peers at a time, so the loss of a peer does not necessarily mean that the data also is lost. The distributed database can also be used to store the information needed for the location function described above.

Also another type of nodes exist namely the P2PSIP clients. Clients interact with the overlay through one or more associated peers. Clients do not run a distributed database algorithm but they allow the P2PSIP applications to access the database. The P2PSIP network architecture can be seen in Figure 7.

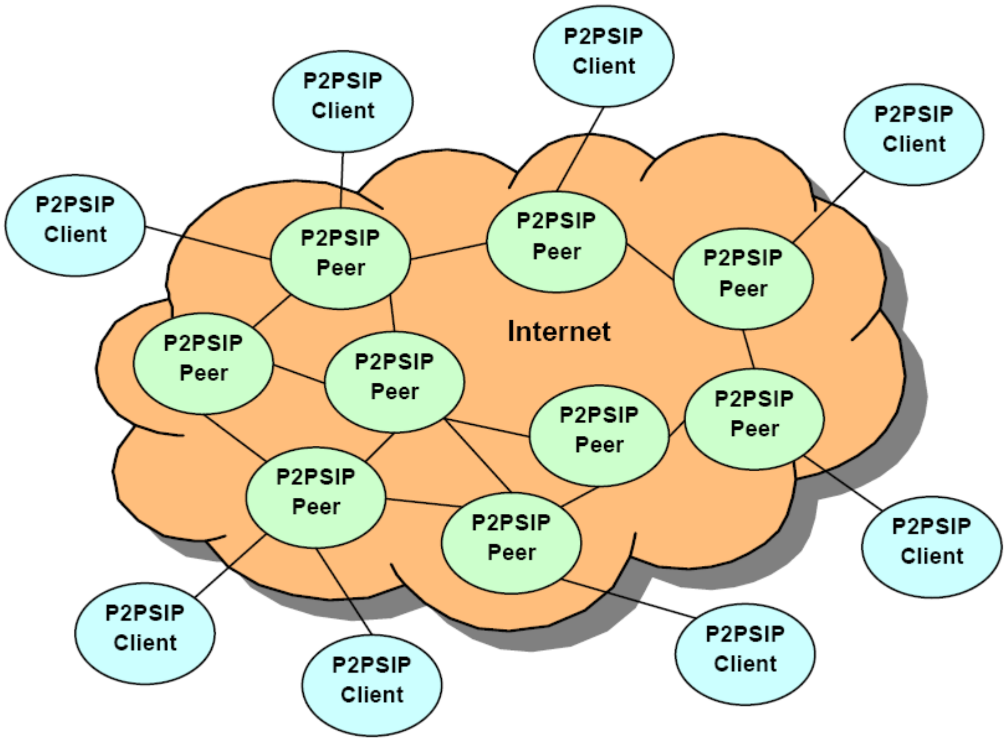


Figure 7: The P2PSIP network Architecture (adapted from Harjula, 2007)

P2PSIP & Mobile Operator

Seppänen (2007) studied the prospects of P2PSIP on vertically integrated mobile operators. Porter (1980, p. 300) has defined vertical integration as '*the combination of distinct production, distribution, selling, and/or other economic processes within the confines of a single firm*'. Thus a vertically integrated mobile operator is for example one which acts as a mobile service operator and a mobile network operator simultaneously. In addition to identifying possible roles and prospects for mobile operators in P2PSIP, Seppänen predicted the impacts of P2PSIP on mobile operators. As the development of P2PSIP is still ongoing the impacts are naturally hard to estimate, but some conclusions can be made.

The business models of charging for telephony might be challenged because of P2PSIP, as has already happened with Internet Service Providers (ISP) and Voice over IP (VoIP) according to Seppänen. P2PSIP might also affect the profitability and role of the IP Multimedia Subsystem (IMS) at some level. IMS is a mobile and fixed multimedia service enabler whose main purpose is to merge the cellular world and the Internet together (Camarillo and Garcia-Martin, 2004). It could also turn out that IMS is already widely deployed and accepted when P2PSIP standard enters the telecom environment, and thus P2PSIP would not be that big a threat to the mobile operators. Even if IMS would reign, P2PSIP could bring some benefits to the operators for instance by providing commercial P2PSIP applications transparent for the customer.

2.2.6 Mobile web servers

The functionalities available usually only on normal computers are becoming general on the mobile phones. For example, one can have a web server running on an advanced mobile phone, of course with limited functionalities in comparison to normal web servers. Nevertheless, advanced mobile phones have the capabilities of running a server and this way everyone can, for example, make their own mobile websites and use the mobile phone as a content provider (Wikman et al., 2006). A consumer oriented, ready to use, mobile web server is available at Nokia's website[14].

Nokia Research Center (NRC) has been researching the area of mobile web servers, and a publication from Wikman et al. (2006) clearly shows that the implementation of these servers is feasible, although there still are issues to be solved. A high level architecture of mobile web server can be seen in Figure 8.

[14] http://mymobilesite.net/ [Accessed 12.11.2008]

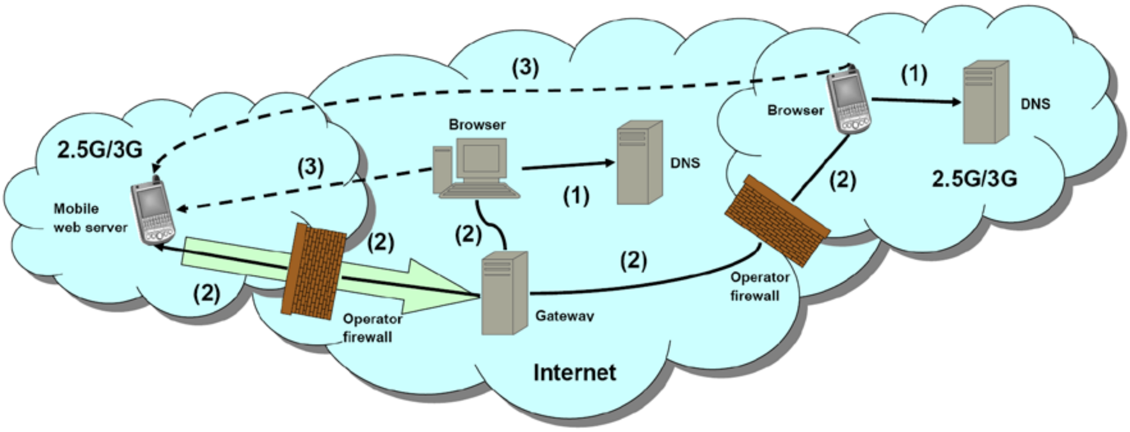


Figure 8: High level architecture of mobile web server (adapted from Wikman et al., 2008)

Wikman has introduced how mobile web servers could be used for sharing calendar information within a group of colleagues. When each phone has a URL referring to the mobile web site of that phone, and a web service interface for a calendar, it is very easy to create a P2P based calendar application without a centralized server. Normally sharing your calendar information with colleagues requires a centralized server that contains the calendar information. Also, when you can access the calendar on the phone or through a web browser on a PC, there is no need for synchronization.

This kind of a calendar really only becomes useful when it is made to be accessible to other people and for example arrange meetings. However, as in MP2P networking in general, there are some issues involving the connectivity between devices as the network operators typically employ Network Address Translation (NAT) and firewalls to prohibit the devices outside the operator network to connect to the network. Also the battery consumption is an issue – when an external party connects to the web server running on the mobile phone it can increase the battery consumption without the owner of the phone being aware of it. The battery consumption can be reduced by only running the web server and not allowing others to access it, but then naturally the above described calendar is also not accessible.

In addition to the calendar application the mobile web server can also be used for instance for sharing content residing in your mobile phone with a group of friends or family. This would be simpler and also cheaper if compared to e.g. sending MMS

(Multimedia Messaging Service) messages. When you want to share the content globally, uploading to a regular web site naturally makes more sense.

Mobile web servers can also be used in searching for mobile content from a user's social network (Tiago et al., 2008). The address book on the server can be used to find out the neighbors of the user and then the content can be queried. The advantage of this approach is that the need for a central search engine gets eliminated and it is easier to find content that might be personally or socially connected to you.

Muilu and Syrjänen (2008) have explored the possibility of creating a MP2P personal media and presence sharing community using personal web sites located in mobile handsets. Users share their experiences through photos, videos, blog entries and comments in the community. The users could also include for example real-time presence and location information to the mobile web site as well as publish the most suitable communication method at a given point of time. The community network can be created by linking other users' web sites to your own web site.

The number of advanced mobile phones is increasing rapidly and in the future their amount will surpass the amount of regular websites (Wikman et al., 2006). Adding a mobile web server to every advanced mobile phone would take the number of mobile websites beyond the number of regular websites and this must have an effect on the development of the web as a whole.

In addition to the mobile web server developed at NRC, the Open Mobile Alliance (OMA, 2008) is also developing its own OMA Smart Card Web Server (SCWS) which is a mobile web server running on a smartcard (e.g. SIM, USIM, UICC, R-UIM, CSIM) in a mobile device.

2.3 Content distribution

Content distribution is one of the main services of P2P together with communication. Other services include gaming, distributed computing and sensor networks.

In fixed networks P2P content distribution became popular with the emergence of high-speed residential internet connections, more powerful desktops and cheaper storage. Now this trend is moving towards the mobile environment as we can witness a similar development in the mobile handsets, although the power consumption remains a bottleneck (Nurminen and Nöyränen, 2008; Kelenyi and Nurminen, 2008). Sigurdsson et al. (2007) also conclude that there currently exists a prospective P2P content distribution market which is bound to continue to grow in the future. Mobile operators have invested heavily in 3G licenses and network equipment, and with the higher transmission capacity they wish to acquire more revenue with new data services.

2.3.1 Content

Heikkinen and Hämmäinen (2007, p.2) have defined content as '*a single media item or a group of media items available to the end user from a service'*. Content e.g. music, movies and pictures can be divided to two major domains namely user-generated and commercially generated content. Commercially generated content is professionally created by the content industry and it can further be divided to three categories as Feldmann (2006) has done. *Promotional sample content* can be used as a tool for promoting professionally created content with a link to subsequent purchasing options. In *user-contextualized content* personal messages and professionally produced content are integrated in order to be able to make pieces of purchased content available to friends for commenting. The third option namely *branded content* is produced and financed by advertisers and used for brand building and customer relationship management. On the user-generated content i.e. personally created media files side generation or consumption of content is becoming easier with the modern powerful mobile handsets with large memories and for example digital cameras. In fact Lehtinen (2006) claims that the shared content in mobile networks will most likely be mainly created by the users.

Content can also be divided to dynamic or static content. Dynamic content is usually unique and created by the mobile devices sensors, whereas static content is created by the user and not context dependent (Tiago et al., 2008).

2.3.2 Content distribution systems

A P2P content distribution system (Figure 9) creates a distributed storage medium enabling publishing, searching and retrieval of files by the peers in the content distribution system's network.

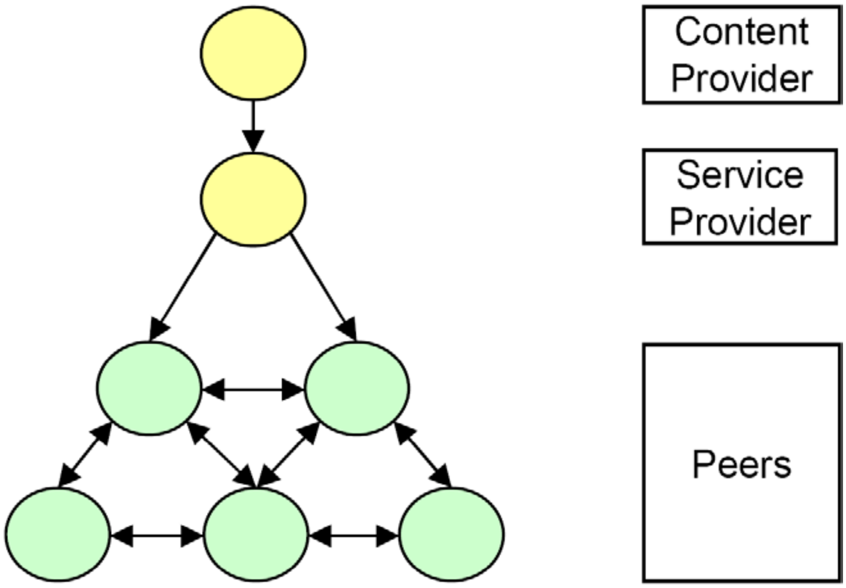


Figure 9: P2P content distribution system

Androutsellis-Theotokis and Spinellis (2004) have grouped P2P content distribution systems to *P2P "file exchange" systems* and *P2P content publishing and storage systems*. The former systems are designed for exchanging files between peers i.e. setting up a network and enabling searching and transferring files between the peers in it. These are usually designed in a best-effort manner without addressing security, availability or persistence. The latter systems on the other hand focus on security and persistence and often aim to include accountability, anonymity, censorship resistance and persistent content management facilities. As mentioned above a content publishing and storage systems creates a distributed storage medium through which peers are able to publish, store and distribute content in a controlled manner according to their privileges.

The most important attributes of P2P content distribution are also described by Androutsellis-Theotokis and Spinellis as follows. *Security* in terms of *integrity and authenticity* i.e. ensuring that the data and processing methods are accurate and complete, *privacy and confidentiality* i.e. ensuring that only authorized access is allowed and *availability and persistence* i.e. ensuring that authorized users can access the data and associated assets when needed. Secondly there is *scalability* i.e. being immune to the number of nodes or documents in the network by maintaining system performance. Thirdly *performance* i.e. the time needed for operations like searching, publication and retrieval of files. Fourthly *fairness* ensuring that users can offer and consume resources fairly and equally and lastly *resource management and grouping* i.e. making more advanced resource management capabilities in more sophisticated systems available and enabling grouping of content and information in different schemes.

Mobile content distribution

The biggest question in mobile content distribution is whether the users really need or want to use content distribution services in their mobile devices. A recent study presents that at least in Finland there is a need for MP2P content sharing applications with an interest both in user-generated and professionally created content (Matuszewski et al., 2007). As stated before, mobile content distribution is characterized by user-generated content because of the digital cameras and other content creation capabilities of modern handsets.

2.3.3 Digital Rights Management

The main idea behind DRM is the usage of licenses – the user who wants to acquire certain content can get the content itself freely, but in order to have access to the content the user has to buy a license. Buying the license happens usually through a third party called a clearinghouse. Through licensing content providers and owners are guaranteed compensation and illegal redistribution can be prevented. Users can also license and share legally their own content using Creative Commons[15] and other open licensing schemes. The basic components of a DRM system can be seen in Figure 10.

[15] http://creativecommons.org/ [Accessed 12.11.2008]

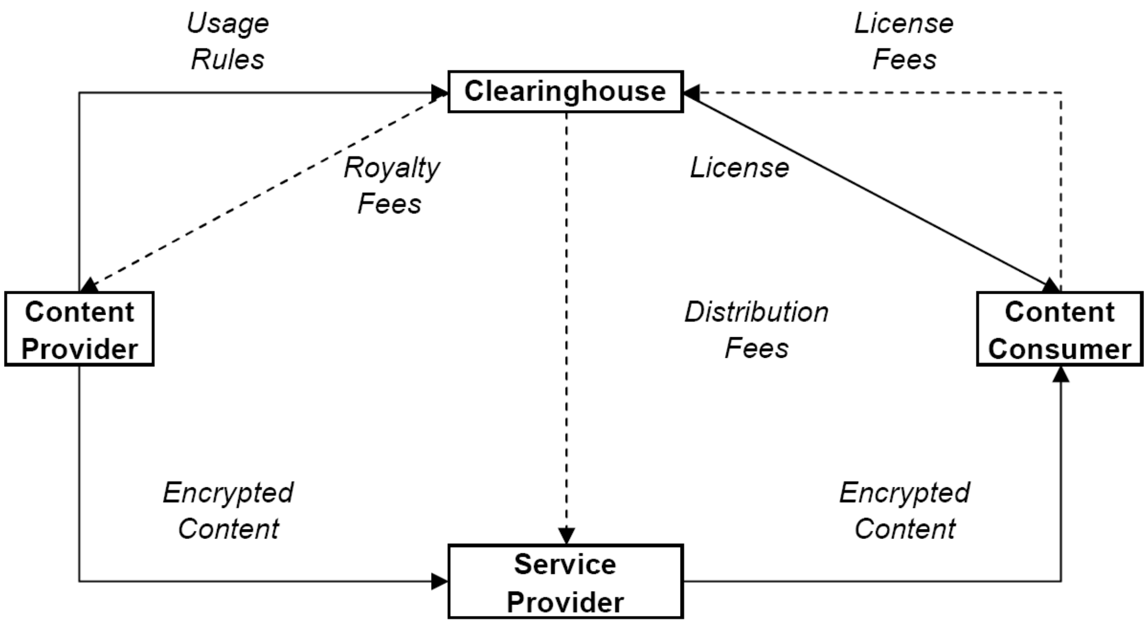


Figure 10: Basic components of a DRM system

Haber et al. (2003) have discussed the technologies needed to implement working DRM systems. First of all there has to be some kind of a mechanism in the system which evaluates if the action conforms to the license i.e. whether the action of the user is blocked or allowed. The licensee has also to be authenticated somehow and the content associated with the license. Without authentication a malicious user could delude the license evaluation engine into thinking it is an authenticated user. The binding between content and license is usually accomplished through cryptographic means.

The problem with DRM is that there always are tradeoffs between security and usability that have to be made. If for example the protection system is too restrictive or DRM degrades the value of the media in terms of for example quality, consumers may not buy the media file.

Superdistribution

Schmidt (2008) has discussed the superdistribution of digital goods in a recent article. Superdistribution means that a peer redistributes legally acquired content to other peers who can access the content by buying the rights. When the other peers buy licenses the distributing peer can get a monetary or social credit from the clearinghouse. Thus it can be seen as a combination of P2P and DRM. Kostamo et al.

(2007) found out in their study that superdistribution is attractive to the peers both in commercial and personal use, although the peers are more eager to distribute their self created content. This means that the incentives for peers to superdistribute are primarily social and then monetary. A digital goods superdistribution system can be seen in Figure 11.

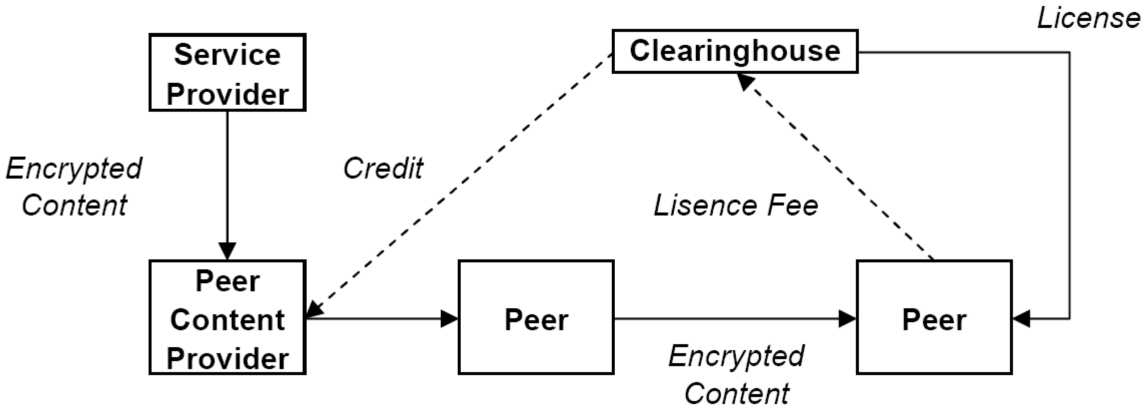


Figure 11: A digital goods superdistribution system

2.3.4 Content distribution types

The next three subchapters introduce three different content distribution types from the fixed network and it will be analyzed what their roles are in the mobile environment.

P2P file exchange

In Internet there are currently many P2P file exchange communities that use different P2P protocols. From these protocols *BitTorrent* is probably the most noted one. P2P file exchange can happen legitimately but there is also so called “gray” or “illegal” file sharing, which means that files which are subject to copyright or censorship are exchanged. Also user-generated content based on copyrighted content, so called “remixes” can be seen as gray file sharing. To tackle the illegal file sharing, different systems have been developed, for example, Microsoft’s file sharing technology *Avalanche*[16]. Microsoft claims that Avalanche prevents redistribution of copyrighted material by forwarding only files that have been signed by the publisher (Gkantsidis and Rodriguez, 2005).

[16] http://research.microsoft.com/camsys/avalanche/ [Accessed 27.11.2008]

As mentioned before Free Riding and the effect of Long Tail are common problems in P2P. In file sharing free riding happens when the peers only download files form the P2P network and do not contribute i.e. upload enough data to the network themselves. The effect of the long tail on the other hand means that the most popular files are duplicated possibly hundreds of times whereas most of the files are only duplicated a few times.

Peer to-peer file exchange is also already possible in the mobile environment using for instance the mobile version of BitTorrent called *SymTorrent*[17] or the Gnutella-based *Symella*[18]. Also according to a recent report by M:Metrics (2008), P2P sharing of music files in mobile environment is more popular than the actual downloading of files from a music service.

Commercial P2P content distribution

Commercial P2P file exchange systems are legal systems that collect revenue from media item sales. The problem behind commercial content distribution is that when someone buys certain content from a content provider, he or she can alter and redistribute the content further in a P2P fashion without the content owner and provider getting compensation. DRM and superdistribution systems described above can be used to prevent unauthorized access to content and manage content usage rights, although it can also be questioned whether content can be protected at all (Haber et al., 2003).

In fixed Internet there has been preliminary activity in the area of commercial P2P superdistribution. Systems like the *BitTorrent Entertainment Network*[19] (BTEN), which was an attempt by the BitTorrent Company of trying to convert the illegal downloaders using their software to legal paying customers, have been implemented but since shut down. On the mobile side the concept of mobile P2P superdistribution has been introduced already for example by Reti et al. in 2002 but at the moment there are no working implementations / prototypes of the concept that the author is aware

[17] http://symtorrent.aut.bme.hu [Accessed 12.11.2008]

[18] http://symella.aut.bme.hu [Accessed 12.11.2008]

[19] http://www.bittorrent.com/btusers/nowplaying [Accessed 28.11.2008]

of. Kumar and Hämmäinen (2005) also concluded that mobile operators have a first-mover advantage in roll-out of commercial MP2P content delivery, but still this advantage hasn't been utilized.

P2P content streaming

One of the types of content distribution is streaming using P2P overlay networks. The streaming includes real-time streaming and streaming stored content i.e. Video on Demand (VoD). P2P networks are considered the most suitable targeted infrastructure for real-time streaming (Mushtaq and Ahmed, 2008) in spite of their dynamic characteristics that can radically worsen the performance of these applications. Sigurdsson (2005, p. 4) has presented a hypothesis describing the necessary conditions where P2P aided streaming can prevail: '*P2P aided streaming will only prevail if it offers higher utility to both peers and service providers than traditional streaming services, given the same quality level.*'.

Peer-to-Peer TV (P2PTV) is one of the applications of streaming-type content distribution, where IPTV services are run on top of a P2P network. IPTV itself is already a widely deployed service which, in comparison to traditional TV, gives the users more options and control over TV-channels without geographical constraints. IPTV services over fixed P2P networks are widely used and some existing architectures, like *PPLive*[20] and *Zattoo*[21] have recently been analyzed in a paper by Krieger and Schwessinger (2008). There are two types of business models for P2P streaming – commercial and non-commercial. In commercial streaming users can not broadcast their own content and the content is authorized. This requires superpeers which compensate for the asymmetric bandwidth. *Zattoo* is an example of a system providing commercial P2P streaming. In a non-commercial system everybody can broadcast for free and there are no dedicated superpeers. Non-commercial systems include e.g. *SopCast*[22] and *PPLive*.

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[20] http://www.pplive.com/en/ [Accessed 27.11.2008]

[21] http://zattoo.com/ [Accessed 27.11.2008]

[22] www.sopcast.com/ [Accessed 27.11.2008]

In the mobile environment there are some challenges and open issues of P2PTV to be solved that Mushtaq and Ahmed (2008) have identified. However some MP2P streaming applications, like the Mobile Opportunistic Video-on-demand (MOVi) (Yoon et al., 2008) have been developed.

2.4 Stakeholders

Stakeholders are actors, typically organizations that have an interest and can influence or be affected by the issue in question.

There are a lot of stakeholders in a MP2P system. Heikkinen and Hämmäinen (2007, 2008) have done some research on the topic in general and Matuszewski (2005) has concentrated on content distribution. At one end there is the *end user* who can consume, create and own content and at the other end there is the *network operator* who provides the transport network. Thus the end user can be seen as three separate stakeholders, namely the *peer content consumer*, *peer content provider* and *peer content owner*. An end user as content provider can be implemented for instance using mobile web servers. A *network service operator* provides access to the transport network and each network operator can serve multiple network service operators as is the case in the current cellular network with several Mobile Virtual Network Operators (MVNOs).

On the provider side there firstly is the *service provider* who provides the MP2P service. The *content provider* provides the content for the service, and a *content distribution network provider* facilitates the distribution of content by providing a network for it. A *content aggregator* runs a portal that is visible to the peers as another peer, but it shares professionally created content. The service provider can be served by multiple content and content distribution network providers. The *content owner* owns the content and can be an individual or a corporate entity.

The devices have to be manufactured and that is the role of the *device manufacturer*. After the manufacturer the *device vendor* sells the devices with the P2P functionality possibly inbuilt either to the end users directly or to the *device retailers* that distribute the devices to the end users.

When going deeper to the supply chain, there are *network and hardware manufacturers* and *software developers* who supply service providers and device vendors. Although the network manufacturers do not play a direct role in the value network, they are important in the long term having a say in which new technologies get developed (De Reuver et al., 2008). Software developers or application providers as Matuszewski (2005) calls them, develop for example MP2P content sharing applications. *Network vendors* also supply the operators.

When Digital Rights Management (DRM) is included to the picture, an additional stakeholder can also be identified. With the help of DRM content owners can securely attach the right management information to the content they have distributed and thus protect their Intellectual Property Rights (IPR). This can be done using a *clearing house* (Liu et al., 2003), which handles the financial transaction for issuing the digital license for a consumer who wants to consume certain content. The clearing house also pays royalty fees to the content provider and distribution fees to the distributor i.e. the service provider. Finally there is the *regulator* on top that imposes regulation on the other stakeholders. Regulators can be national agencies or agencies of larger communities such as a European Union level agency.

Dual roles among the stakeholders are possible – content providers can also be content owners and network operators can be the same entity with network service operators to name a few. A recent example of dual roles is Nokia's Ovi[23] service, which makes Nokia act as a service provider and as a device vendor simultaneously. In MP2P end users usually are content consumers, owners and providers at the same time so there can be even more roles among the stakeholders.

2.5 Incentives

Different stakeholders have different incentives why they would want to engage in MP2P content distribution. Heikkinen (2008) has conducted a questionnaire study of the development of MP2P services and technologies in Finland during 2008-2012 and the report gives some guidelines what added value MP2P could give to the different

[23] http://ovi.nokia.com/ [Accessed 12.11.2008]

stakeholders. Also Matuszewski (2005) has done some research of the value proposition of different stakeholders in MP2P.

End users

First of all there are the end users, who are critically important in the MP2P value network. If the users do not see any additional value created for them in MP2P they will not adopt the technology. There has been a lot of research on the end user incentives of sharing resources in P2P networks. According to the questionnaire by Heikkinen cost savings, content access, efficiency, network formation and easier configuration create value for the end users. Cost savings are realized for example through cheaper services. In a study by Lee (2003) the fact that there is no fee charged was conceived as the most important feature of P2P systems from the end user perspective. However, another survey (Matuszewski, 2005) indicates that choice and convenience are the key drivers of P2P systems instead of price. Content access refers to the availability of content – MP2P can be used to acquire content that would otherwise be hard to find. Publishing, searching and retrieving content is also efficient using MP2P and it requires less configuring. MP2P is seen as a means of meeting new friends, interact with people and form networks so it can have sociological effects as well. On the sociological side, Feldmann (2006) also argues that identity construction in social networks can be an essential incentive for personal file-sharing in MP2P networks. In the case of mobile content superdistribution users can get additional value by redistributing content and getting a provision from the content provider in the form of reputation or money. Raivio (2005) has discussed that there might also be financial incentive for users in the form of Consumer-to-Consumer (C2C) business – users could store and price their own content on a mobile proxy for further selling. The end user incentives are summarized in Table 2 below.

Table 2: End user incentives in MP2P content distribution

1. Cost savings	5. Network formation
2. Easier access to content	6. Identity construction
3. Efficiency	7. Provisions
4. Easier configuration	8. C2C-business

Mobile operators

For mobile operators cost savings is a major value creator too. In addition to that MP2P could increase the demand for mobile services and usage of mobile data networks. More expensive phones and flat-rate mobile data access could be sold. The operators could have control over content and wider service offering as well as increased scalability and fault-tolerance. The existing bandwidth could be better utilized and charging options increased. The distributed nature of the system would allow distributing resource requirements and also experimentation, which is crucial in high market uncertainty situations (Matuszewski, 2005). Raivio (2005) has stated that the biggest incentives for operators would be entering a novel market place and improving distribution channels. The incentives for mobile operators are summarized in Table 3 below.

Table 3: Mobile operator incentives

1. Cost savings
2. Increased demand for mobile services
3. Increased usage of mobile data
4. Increased sales of more expensive phones
5. Increased sales of flat-rate subscriptions
6. Control over content
7. Wider service offering

Service providers

MP2P could offer third-party service providers major cost savings for content distribution and possibilities for new applications. This way though the burden of P2P transit traffic would only be passed to the Internet Service Providers (ISP). Parker (2004) has stated that this could result in annual costs of one hundred million Euros for ISPs in Western Europe alone, and a more recent study by Dickson (2008) claims that P2P causes capital expenditures of 4.1 Billion dollars for US ISPs. Some service providers could use MP2P as a tool for aggressive market take-over and new business models. Service providers could also have easier access to end-users possibly without operator agreements, deploy and administer services more easily as well as implement and offer services more cheaply. The incentives for service operators are summarized in Table 4 below.

Table 4: Service provider incentives

1. Cost savings	5. Easier access to end users
2. New applications	6. Easier deployment and administration of services
3. Market take-over	7. Cheaper implementation and offering of services
4. New business models	

Content providers

For content providers lower costs, larger demand, more efficient content distribution and possibility to deliver niche content are identifies as value creators. Content distribution could be implemented more cheaply and efficiently for example through superdistribution. Increased revenue could be acquired through larger demand and possibly via mobile operators' customer base. Marketing expenses could be reduced because of the peer-effect. According to Sainio and Porras (2004) content providers could also gain additional value if they would have more optional content distribution routes with various price levels with for instance the help of a content distribution network provider. The incentives for content providers are summarized in Table 5 below.

Table 5: Content provider incentives

1. Cost savings	4. Delivering niche content
2. Larger demand	5. Reduce marketing costs
3. More efficient content distribution	6. More optional content distribution routes

Equipment vendors

For incumbent mobile application / equipment providers such as Nokia, Siemens and Ericsson MP2P represents a threat to the matured centralized technology and might incur cannibalization. Thus new entrants will probably find MP2P more interesting. The faster the adoption of 3G services is, the higher the investments in better service coverage become. Thus this can lead to higher revenue for mobile equipment vendors (Matuszewski, 2005).

2.6 Related scenario work

Heikkinen et al. (2008) have used Schoemaker's scenario analysis (Schoemaker, 1991, 1993, 1995) in studying the emerging Mobile Peer-to-Peer Session Initiation Protocol (P2PSIP) communications services in a hypothetical Western European country during 2008–2012. They have identified the trends, stakeholders and uncertainties using literature sources and results of a questionnaire, and finally identified eight learning scenarios. From these scenarios they have identified *small ad hoc* and the *local private* as the most favorable scenarios. By ad hoc is meant that the P2PSIP communications service is formed in an ad hoc basis by independent mobile devices. The local private scenario means that the users are in a single administrative domain and can trust each other. Thus the firewall and Network Address Translation (NAT) -constraints as well as the security level needed are low. These results however are only qualitative and they have left the construction of quantitative models for later study.

Heikkinen and Hämmäinen (2007, 2008) have applied scenario analysis in analyzing the MP2P service usage in Finland during 2008-2012. They have also used Schoemaker’s method and developed three learning scenarios based on a questionnaire study and literature review. These scenarios are called *Open MP2P*, *Restricted MP2P* and *Operator-controlled MP2P*. The open scenario means that the operator does not have control over third-party MP2P service development and deployment i.e. the firewall policies are open. Also flat rate is the dominant pricing model. In the operator-controlled scenario things are the other way around and only operator-approved MP2P services are allowed in mobile networks. The firewalls are restrictive and the pricing model is service flat rate i.e. a flat rate tariff restricted to one or more distinct services. The restricted scenario in the middle either has restrictive firewalls and open flat rate, or open firewalls and service flat rate. The authors however stress that the scenarios do not result in a detailed understanding of the future, but instead try to limit the potential outcomes into three rough domains. They intend to use the results as a starting point for further techno-economic analysis of MP2P.

3 Research methods

This chapter introduces the research methods used in the thesis. First the scenario analysis process is presented and especially Schoemaker's version of it. After that a brief introduction to system dynamics is presented together with the modeling process and other elements used in the model construction. Lastly the two brainstorming sessions are introduced which were held as a part of the scenario construction process.

3.1 Scenario analysis

Scenarios can be defined in various ways, but in this thesis we use the following definition by Schoemaker (1993, p.3): scenarios are '*focused descriptions of fundamentally different futures presented in coherent script-like or narrative fashion*'.

Scenario analysis as a method was introduced in the late 1960s by Shell Corporation. It was used to outline future outcomes of the oil markets and predict the 1973 oil crisis (Wack, 1985a, 1985b). At the same time the concept of *la prospective* (Godet, 1982) was introduced and together these approaches inspired the development of actual scenario analysis methods.

In the telecommunications field, Ballon (2004) has applied scenario analysis to investigate the trends and uncertainties of the fourth generation mobile systems and services in Europe. Karlson et al. (2003) have also predicted the development of the wireless communication industry and technology using scenario analysis.

Scenario analysis is not about forecasting the future as one might think, but rather about bounding the uncertainty related to the alternative futures (Schoemaker, 1991). The main idea behind scenario analysis is to simplify a vast amount of data into limited number of possible futures i.e. scenarios. These scenarios are organized as narratives, which makes them easier to grasp than large volumes of raw data.

Schoemaker (1995) has compared scenario analysis to other planning methods such as contingency planning, computer simulations and sensitivity analysis. Regarding the uncertainties scenario analysis takes into account multiple uncertainties whereas contingency planning examines only one uncertainty. In comparison to computer simulations, scenario analysis often includes elements that cannot be formally modeled and thus include subjective interpretations to objective analysis. In sensitivity analysis only one variable can be changed at a time while others are kept constant whereas in scenario analysis several variables are changed at a time and thus new states in key variable after major deviations can be captured.

Schoemaker (1991) has also compared scenario analysis to statistical techniques, decision analysis and traditional forecasting. Schoemaker views scenario analysis as complementary to stochastic simulation and decision analysis whereas the differences between traditional forecasting and scenario analysis are identified. Forecasts are often wrong but become better as the environment stabilizes. Scenario analysis on the other hand tries to highlight the reasoning behind forecasts with the focus on uncertainty and thus scenario analysis can be seen as more valuable in unstable environment.

There are no universal rules for conditions when usage of scenario analysis is favorable, but Schoemaker (1995) has identified following conditions that he thinks favor the use of scenario analysis (Table 6).

Table 6: Favorable conditions for using scenario analysis

1. The uncertainty is high
2. Too many expensive surprises occurred in the past
3. Insufficient new opportunities are perceived or generated
4. The quality of strategic thinking is low
5. The industry has experienced significant change
6. A common language and framework is desirable
7. Strong differences of merited opinions exist
8. Competitors use scenario planning

Thinking about the scope of this thesis, one can quite surely say that the conditions 1, 2 and 5 favor the use of scenario analysis as a research method in this case.

Schoemaker's method

Schoemaker's scenario analysis method consists of ten steps. The steps in Table 7 are adapted from (Schoemaker, 1993, 1995).

Table 7: Shoemaker's scenario analysis steps

1. Define the time frame, scope and decision variables
2. Identify the major stakeholders
3. Identify the trends or predetermined elements
4. Identify key uncertainties
5. Construct initial forced scenarios
6. Check for internal consistency and plausibility
7. Develop consistent learning scenarios
8. Assess stakeholder behavior in the scenarios
9. Develop a quantitative model
10. Iterate towards decision scenarios

The first step is to define the time frame and scope of analysis. After defining the time frame for instance according to product life cycles or the rate of technology change, the scope and decision variables i.e. what knowledge is of greatest value within the time frame should be identified. It is useful to look back the same amount of time that is to be looked forward in order to help identifying the scope and decision variables.

In the second step the major stakeholders should be identified. Stakeholders are actors that have an interest in the issue in question and are affected by it or influencing it. Also the roles, interests and power positions as well as how and why they have changed over time should be identified.

In the third step a list of the trends and predetermined elements that affect the issue of interest should be constructed. Each trend should be explained briefly so that the influence of the trend and the reason behind it come clear. In this step everybody has to agree that these trends will continue, if not then the trend belongs to the next step.

Identifying the key uncertainties is the fourth step. Uncertainties are events or forces which will affect the issue of interest but whose outcomes are uncertain. The uncertainties should be briefly explained in terms of significance and interrelations and the possible outcomes should be determined.

The forced scenarios are constructed by putting all the negative elements to one scenario and all the positive elements to the other. This is accomplished by grouping the trends and studying their interrelations and by studying the correlations of the uncertainties. Another method is to select the two most important key uncertainties and cross them. This works well if there are two uncertainties that are clearly more important than the others.

The internal consistency and plausibility of these forced scenarios should be checked in the sixth step. This means for example eliminating pairs of uncertainties that clearly do not go together or scenarios that are impossible or not credible. Also if the major stakeholders in a scenario are in a position they do not like and can change, the scenario is bound to evolve to another one.

Some general themes should emerge based on the previous step and the goal is to identify the themes that are strategically relevant and organize the trends and possible outcomes around them. From these themes the learning scenarios should be constructed, which includes naming the scenarios and depicting them in a narrative fashion.

The eighth step is to do further research in order to really understand the behavior of the stakeholders and identify topics that would provide stronger support for your scenarios or revise the learning scenarios.

After the additional research it should be checked if some of the interactions should or could be formalized through quantitative models. The models can be used to prevent straying into implausible scenarios and to quantify the consequences of scenarios.

In the last step the decision scenarios should eventually be developed through an iterative process retracing steps from one to nine. These scenarios can be used to test strategies, generate new ideas and given to others in the organization in order to enhance their decision making in uncertain situations.

Schoemaker also gives four criterions to determine if the final scenarios are good or bad. Firstly the scenarios should be relevant i.e. connect directly with the mental models and concerns of the users. As discussed in step six, the scenarios should also be internally consistent. Thirdly the scenarios should be archetypal i.e. not concentrate on variations of a single scenario but rather describe generically different futures. The scenarios should also not be transient but describe an equilibrium point where the system could exist for some length of time so that a possible future for an organization will not be short-lived.

3.2 System dynamics

System dynamics is a systems engineering method for enhancing learning in a complex system. The basis lies in systems thinking i.e. being able to see the world as a complex system where everything is connected to everything and one cannot assume that a change in one variable wouldn't affect anything else (Sterman, 2001). The idea of system dynamics was first introduced in the 1950s in MIT by Jay W. Forrester who later published a groundbreaking book called "Industrial Dynamics" in 1961 (Forrester, 1961). Since then system dynamics has been used widely covering different disciplines for example in strategy planning and social sciences (Sterman, 2000).

In this chapter the basic concepts of system dynamics and the fundamental modes of dynamic behavior are introduced. Mental models and their role in system dynamics are also explained and finally the modeling process is described.

3.2.1 Basic concepts

The structure of a system is described with causal loop diagrams and stock and flow diagrams in system dynamics. The mathematical model is hidden underneath it and the diagrams show the interactions and feedbacks of variables within the system. The following basic concepts are adapted from Sterman (2000).

Feedback

Feedback is an essential concept in system dynamics. System dynamic models are basically networks of feedbacks and the dynamics of systems arise from the interaction of these feedbacks. There are two types of feedback loops that all dynamics arise from, namely positive and negative. Positive loops reinforce (R) and negative loops oppose and thus balance (B) change. Figure 12 describes the feedback loops – the more chickens, the more eggs and vice versa – the more chickens, the more they have to cross roads and get killed by cars.

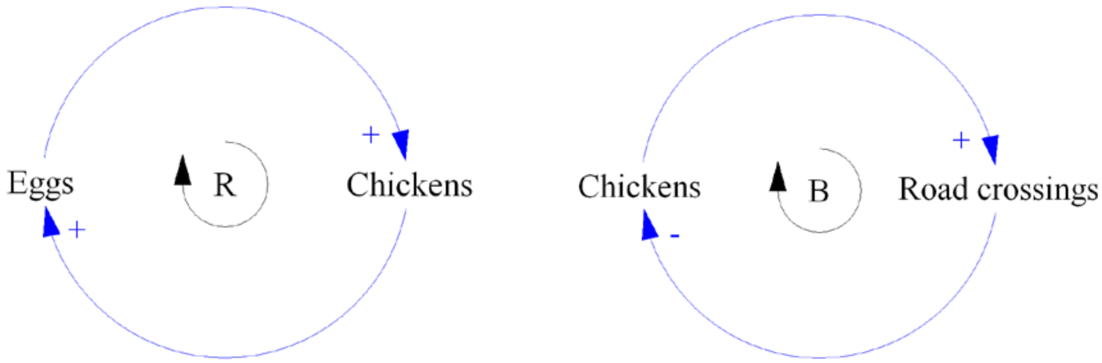

Figure 12: Positive and negative feedback loops (adapted from Sterman, 2000)

Causal loop diagram

Causal loop diagrams (Figure 13) describe the causal connections between components and thus represent the feedback structure of the system. Causal diagrams consist of variables and arrows connecting them. The arrows have either positive or negative polarity as discussed in the previous subchapter.

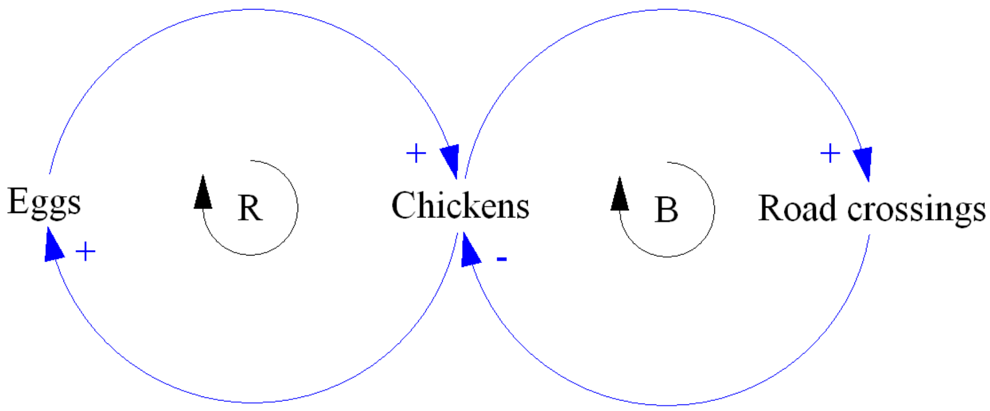

Figure 13: Causal loop diagram of the chicken population (adapted from Sterman, 2000)

Stocks and flows

If the causal diagrams include variables that represent containers that can increase or decrease over time they have to be represented as stocks. In Figure 13 the variables “Eggs” and “Chickens” would be represented as stocks if stock and flow diagramming notation would be used. Flows represent the rate that the stock variables change. General structure of stocks and flows can be seen in Figure 14.

Figure 14: General structure of stocks and flows (adapted from Sterman, 2000)

When the attributes of various items travel through the system's stock and flow structure, coflow structures are used to keep track of them. Coflows are used widely in system dynamics, because often it is needed to keep track of attributes such as capital plant and equipment in relation to labor requirements for example. A generic coflow structure can be seen in Figure 15.

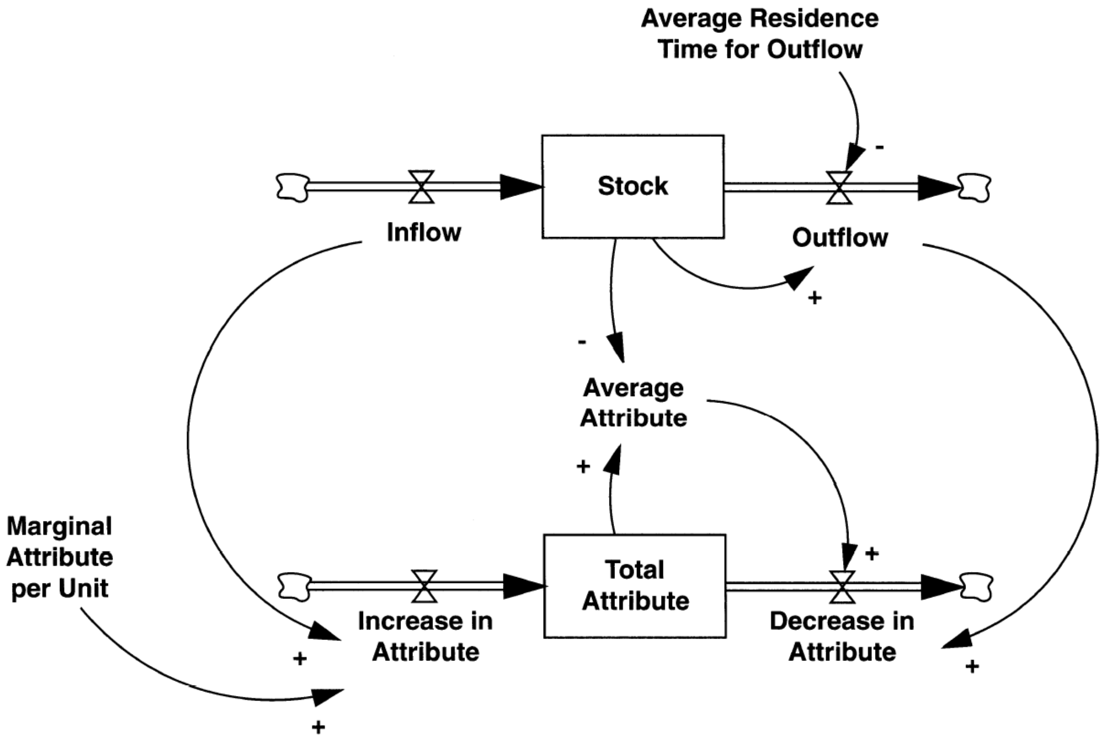

Figure 15: Generic coflow structure (Sterman, 2000)

The basic idea is that when a unit flows into the stock, it adds a marginal attribute to the total attribute. As a unit flows out of the stock, the average attribute is removed. The number of coflows is not fixed and in general there can be any number of flows in and out of the main stock and their corresponding flows in and out of the total attribute.

Time delays

An essential amount of dynamism in systems is created by delays. Delays can create oscillations and instability in negative feedback loops, but on the other hand they can also filter out unwanted variability and thus make it easier to separate signal from noise.

3.2.2 Mental models

Central elements in system dynamics are the ways people understand the world i.e. the mental models of people. Mental models are used for example in decision making but usually they are generalizing and full of flawed assumptions. In addition to this the mental models are always an interpretation of one person and can be difficult to understand for others. Mental models can however be updated in the course of time as people get feedback and learn from their environment.

Flawed mental models are one of the most significant reasons for policy resistance, because people do not recognize feedbacks and consider systems as event-driven (Sterman, 2000). Policy resistance means that systems tend to respond to interventions by trying to defeat them. To achieve realistic results the concept of mental models has to be understood. System dynamics is a good tool for problem solving when problems are caused by dynamic complexity, because it involves tools like causal loop diagrams which help communicating the mental models.

3.2.3 Behavior of dynamic systems

Sterman (2000) has identified three fundamental modes of dynamic behavior, namely exponential growth, goal seeking and oscillation (Figure 16). These fundamental modes all are generated by feedback structures and most of the dynamics in systems are instances of these modes.

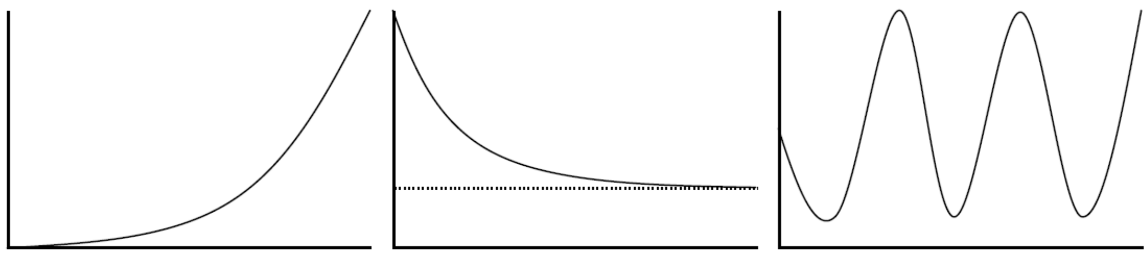

Figure 16: Exponential growth, goal seeking and oscillation (adapted from Sterman, 2000)

Exponential growth stems from positive feedback as was the case with eggs and chickens in Figure 12. Positive feedback does not always result in ever-faster growth, it can also create decline. In goal seeking, there are positive and negative feedback loops. Positive loops work as in exponential growth, but the negative loops correct the state of the system to be in line with the goal if the desired and actual states of the system are different. In oscillation there are corrective actions as in goal seeking, but they constantly overshoot and undershoot because of delays. Thus the corrective actions continue after the goal is achieved and further corrections in the opposite direction are generated.

There are also three other basic modes of behavior that that are combinations of the fundamental modes, namely S-shaped growth, growth with overshoot and overshoot and collapse (Figure 17).

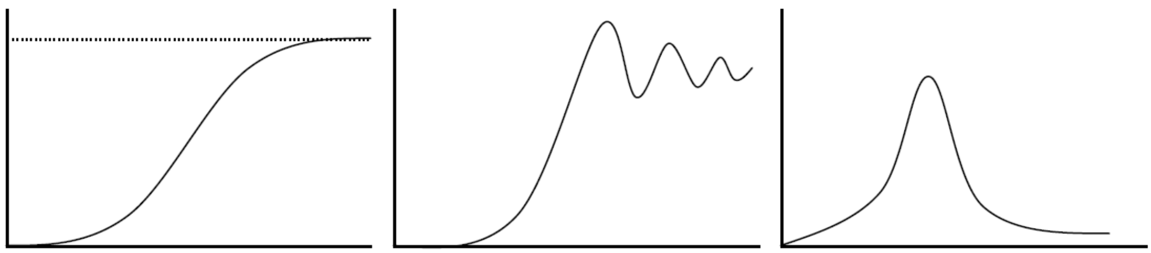

Figure 17: S-shaped growth, growth with overshoot and overshoot and collapse (adapted from Sterman, 2000)

3.2.4 The modeling process

Sterman (2000) has introduced a system dynamic modeling process that will be used in this thesis as well. Modeling is an iterative process and iteration can happen from any step to any other step. Figure 18 shows the steps of the modeling process.

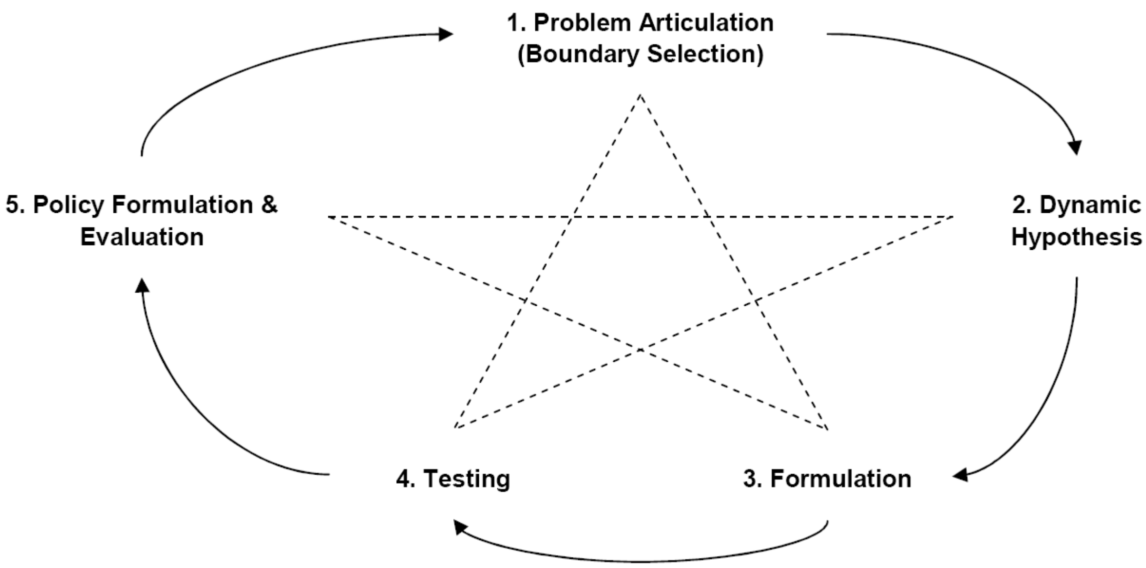

Figure 18: Modeling process (adapted from Sterman, 2000)

The foundation for modeling is to articulate the problem properly i.e. express the purpose of the model clearly. A clear purpose provides the criteria to decide what factors are relevant and what can be ignored. The idea is never to model a complete system but rather model a problem. In this step also the *reference mode* (graphs and other descriptive data depicting the development of the problem over time) and *time horizon* should be clarified.

The next step is to formulate the dynamic hypothesis. A dynamic hypothesis must explain the dynamics that characterize the problem in terms of the feedback and stock and flow structure of the system. A dynamic hypothesis is a theory of how the problem arose and it is always provisional and subject to revision or abandonment. A model boundary chart including the endogenous, exogenous and excluded variables as well as a subsystem diagram should also be constructed.

In the third step the dynamic hypothesis, model boundary and conceptual model should be tested. This is done by formulating a simulation model by depicting the interactions, equations, parameters and initial conditions of variables in detail. Formalizing a conceptual model usually is very complex and the dynamic implications unclear. Thus this step usually requires revising several times.

In the testing phase the simulated behavior of the model is compared to the actual behavior of the system. It is far more than just replicating historical behavior. For example, all equations should be checked for consistency and the model tested under extreme conditions. Also basic of laws of physics should not be violated.

The last step is policy design and evaluation. New strategies, structures and decision rules are created in policy design by changing dominant feedback loops and eliminating time delays for instance. The policies must be robust and their performance under different scenarios consistent.

3.2.5 The Bass diffusion model

The Bass diffusion model (Bass, 1969) is one of the most popular models used for technology adoption and diffusion of innovations in the fields of marketing, strategy and technology management to name a few. Figure 19 presents Sterman's (2000) version of the Bass diffusion model which he has adapted to system dynamics.

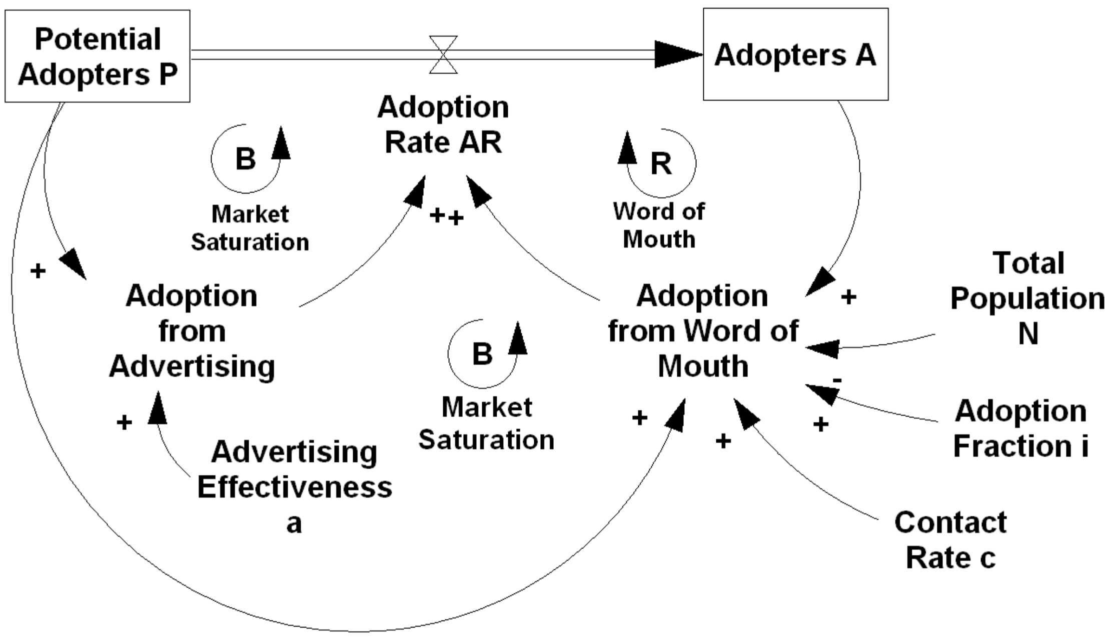

Figure 19: The Bass diffusion model (Sterman, 2000)

As the figure above shows, the total adoption rate is the sum of adoption from word-of-mouth and adoption from advertising. The model is based on the assumption that the magnitude and persuasiveness of word-of-mouth and advertising are roughly constant over time and that they are independent from each other. The effect of advertising i.e. parameter *a*, is the fractional adoption rate from advertising. Thus the adoption from advertising yields *aP*. Adoption from word-of-mouth can be expressed as *ciPA/N*, where contact rate is the amount of potential adopters contacted by adopters during a time period and adoption fraction the fraction of the contacted potential adopters who eventually adopt the technology.

In the introduction of an innovation there are no adopters and thus advertising is the only source of adoption. As the amount of potential adopters decreases, the effects of advertising fall and effects of word-of-mouth increase.

The Bass model can be extended to model product discard and replacement purchases by adding a flow back from adopters to potential adopters. Also modeling repeat purchases is possible where a potential adopter adopts a product and then continues to purchase it thereafter at a constant rate.

3.3 Brainstorming

In addition to the other research methods, brainstorming was used to gather new ideas and more research data. The goal was to have two sessions – one with experts and one with laymen.

3.3.1 Expert session

The first brainstorming session was conducted with a group of experts in order to identify the main trends and key uncertainties related to MP2P. The brainstorming session was held at the Helsinki University of Technology (HUT) on 30th of October 2008.

Participants

The author operated as the facilitator in the session and there were nine other participants. The participants had educational, industrial and academic experience in computer science and telecommunications and were all part of the HUT Communications and Networking Department's (ComNet) Networking Business research team. The participants were the following:

- Professor (ComNet)
- Professor (Turku School of Economics)
- Docent (ComNet)
- Four research scientists (ComNet)
- Two research assistants (ComNet)

3.3.2 Layman session

The purpose of the second brainstorming session was to get a layman opinion about the future of MP2P content distribution in contrast to the expert session described above. The idea was to gather session participants that were not computer science or telecom oriented in terms of education or working experience. This session was held on 18th of November 2008 at HUT.

Participants

Once again the author operated as the facilitator and the other five participants were as follows:

- Two students at the Helsinki School of Economics
- Sales assistant in food industry
- Doctoral student of Physics at University of Helsinki
- Industrial / Graphic Designer

According to the questionnaire conducted in the beginning of the session it became clear that all of the participants had used or tried some data services with their mobile handsets. All of them had also used P2P content sharing and communication services in the fixed Internet. Only one of the participants had experience of using P2P communication services in the mobile domain and nobody had used MP2P content sharing services.

4 Modeling

This chapter begins the author’s own contribution. First the most relevant scenarios in the area of MP2P content distribution are built and then a system dynamics model is built based on the scenarios.

4.1 Most relevant scenarios

Based on the literary analysis and other research the most relevant scenarios regarding MP2P content distribution will be constructed in this chapter. The scenarios are constructed following Schoemaker’s method described in Chapter 3.1.

4.1.1 Time frame, scope and decision variables

As discussed before the time frame for the scenarios is 2009-2013. The scope of the scenarios is limited to MP2P content distribution in Finnish mobile industry and markets. The decision variable is the value of MP2P content distribution services for the end users.

4.1.2 Major stakeholders

Identifying the major stakeholders is quite straightforward based on the literature analysis. In spite of the fact that there are a lot of stakeholders in MP2P, the ones that are the most important in content distribution are quite clear.

Naturally the end users are one of the major stakeholders since they consume but also can create and own content, as well as provide content to other peers for example as a mobile web server. It is assumed that peer content owners can only distribute content through peer content providers. The end user is represented as three separated entities in the major stakeholder network (Figure 20).

The content can be created also by external content providers who provide content for MP2P content distribution service providers, and owned by external parties called content owners.

Content providers can either make agreements directly with the service providers or use the services of a content distribution network provider, like Amazon’s

CloudFront[24], which facilitates the content distribution and makes the content delivery more efficient by placing edge servers where the content is stored nearer to end users.

Access to the mobile network is provided by network service operators. Regulators impose regulations on the other stakeholders and thus must be included in the following list of major stakeholders for MP2P content distribution:

- **S1**: Peer content owner
- **S2**: Peer content provider
- **S3**: Peer content consumer
- **S4**: Content provider
- **S5**: Content owner
- **S6**: Service provider
- **S7**: Network service operator
- **S8**: Content distribution network provider
- **S9**: Regulator

Stakeholders that are not considered that relevant in these scenarios, because they go too deep in the supply chain or are not mandatory components are the network operator, content aggregator, device manufacturer, device vendor, device retailer, network and hardware manufacturers, network vendors, software developers and clearing houses.

The results of a questionnaire study about MP2P conducted by Heikkinen (2008) further reinforce the views presented in this section, since the results are very similar.

Interrelations of the major stakeholders

The major stakeholder network of MP2P content distribution can be seen in Figure 20 below.

[24] http://aws.amazon.com/cloudfront/ [Accessed 03.12.2008]

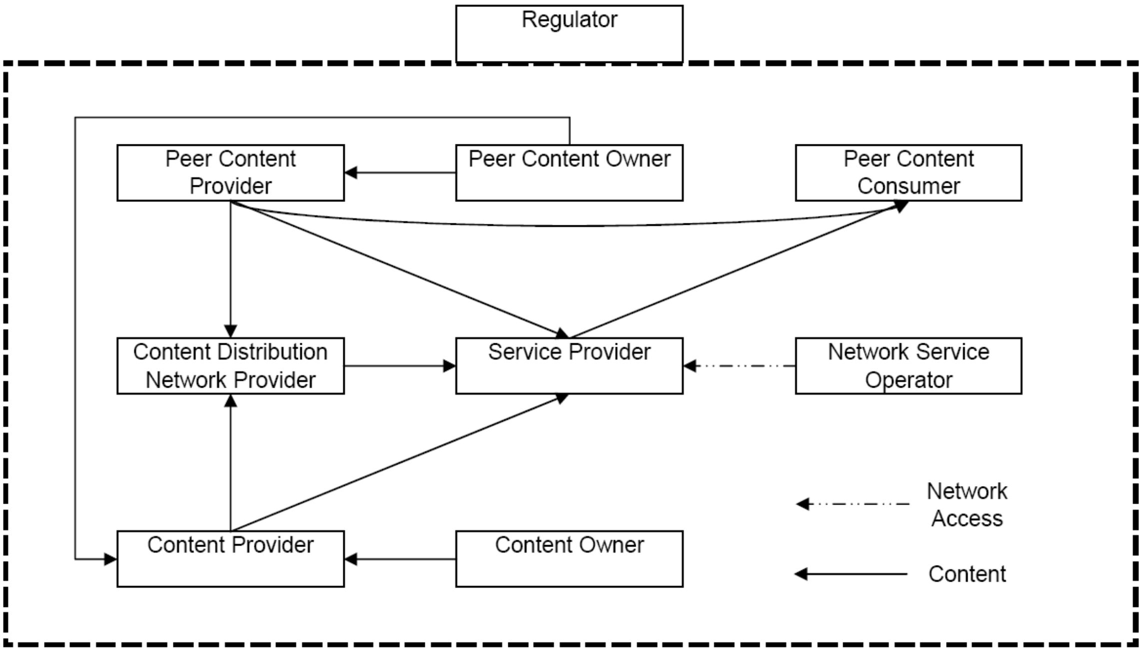

Figure 20: Interrelations of the major stakeholders

4.1.3 Main trends

The two brainstorming sessions were conducted in order to identify the main trends and key uncertainties of MP2P content distribution. Based on the sessions and the literature analysis preceding them the following main trends were identified.

The continuing limitations of mobile devices caused by the battery capacity and power dissipation were unanimously conceived as a main trend in the expert brainstorming session. On the other hand the capabilities of mobile devices in terms of memory, storage capacity and processing power were considered to be growing fast, as well as the amount of multi-radio equipped mobile handsets. Also mobile network capacity will grow, but might remain a bottleneck. This trend was identified in both the expert and the layman brainstorming sessions.

Regarding the pricing model of mobile data services limited flat-rate was conceived to become the dominant one by the experts as flat-rate increases rapidly as we speak. The term limited flat-rate refers to flat-rate with some upper limit of data usage, which would eliminate excessive usage of data. The amount and importance of user-generated content was considered to increase, as well as the amount of legal content in general. Also increased personalized media consumption was conceived as a main trend as the services are evolving from the traditional push-services to pull-services.

In push services the service is "pushed" to the client from the provider, i.e. the transaction originates from the provider. An example of a traditional push service is email where a new message is instantly delivered to the client. Pull services on the other hand require a request for the transmission from the client. Pull technology is used in the Internet in HTTP page requests for instance. The identified main trends and their positive (+), negative (-), indeterminate (?) or insignificant (0) impacts are listed in Table 8 below.

Table 8: Main trends and their impacts

	Trend:	Impact:
T1:	Battery capacity of mobile devices will remain a bottleneck	-
T2:	Capabilities of mobile devices are growing fast	+
T3:	Mobile devices are increasingly equipped with multiple radios	+
T4:	Mobile network capacity will grow	+
T5:	Limited flat-rate will be the dominant pricing model for mobile network access	+
T6:	The amount and importance of user-generated content is increasing	+
T7:	The amount of legal content is increasing	+
T8:	Personalized media consumption is increasing	?

These identified main trends are supported by the MP2P scenario analysis research conducted by Heikkinen and Hämmäinen (2007, 2008) and Heikkinen et al. (2008).

4.1.4 Key uncertainties

The following key uncertainties were also identified in the brainstorming sessions and the literary analysis.

First of all there was uncertainty over operator policy. It was unclear whether the operators would employ open or closed firewalls or limit the usage of MP2P content distribution in other ways such as restrictive NAT policies. Operator policy emerged as a key uncertainty in both of the brainstorming sessions. It was also questioned if the operators have the power to limit MP2P content distribution since the long term success of closed business models seems uncertain. As a result it was uncertain what the revenue logic or business model of mobile operators for MP2P content distribution would be.

From the user point of view it was questioned whether MP2P would provide any extra value in comparison to traditional Client-Server (C-S) approach. On the other hand MP2P was conceived to create value for instance for the "always on the run" people, and thus the value created by MP2P in contrast to C-S was considered a key uncertainty. The participants in the layman brainstorming session were also concerned about security and privacy issues of the end users in MP2P content distribution.

As already mentioned the battery and the network capacity remain uncertain as well. Also the role of the mobile device as a media device was questioned. It was uncertain whether the primary tool for media management would be the personal computer or the mobile device. It was questioned whether the mobile device capabilities in terms of memory and processing power would be adequate. The usability of MP2P and if there would be enough services and users and thus content available in MP2P was questioned. Especially the participants in the layman brainstorming session were wondering if MP2P would be too complicated to use for an average user and if the user interface on the mobile device would reduce usability. The role of Digital Rights Management was also considered to be uncertain. The following list represents the identified key uncertainties after the brainstorming sessions and literature analysis:

U1: Operator policy
U2: Revenue logic / business model for operators
U3: Created value of MP2P over client-server for the end user
U4: End user security and privacy
U5: Battery capacity
U6: Network capacity
U7: The role of the mobile device as a media device
U8: Mobile device capabilities
U9: Usability of MP2P content distribution services for the end user
U10: Availability of MP2P content and services
U11: Digital Rights Management

As with the trends above, these key uncertainties are also supported by the research done by Heikkinen and Hämmäinen (2007, 2008) and Heikkinen et al. (2008).

Correlations of uncertainties

In studying the correlations of the uncertainties listed above some of the uncertainties had to be ruled out since the correlations were either impossible to define or the uncertainties were not consistent. First of all the decision variable, value of MP2P content distribution services for the end user rules out the third uncertainty, since it is expected that it will create value and all the correlations were positive. Uncertainty number nine, i.e. the usability of MP2P content distribution services for the end user, was deemed too complex a variable to use since it is very hard to define the correlations. The usability can also be added to the device capabilities by including the user interface to the capabilities along with memory and processing power. The availability of MP2P content and services was also excluded as the correlations were all positive and its effect was irrelevant. Thus the final key uncertainties in order of importance according to the brainstorming sessions, and their outcomes and impacts on the decision variable can be seen in Table 9.

Table 9: Final key uncertainties and their outcomes and impacts

	Uncertainty:	Outcome:	Impact:
U1:	Operator policy	Open Closed	+ -
U2:	Revenue logic / business model for operators	Advertising Charging	+ -
U3:	The role of the mobile device as a media device	Primary Supplementary	+ -
U4:	Mobile device capabilities	High Low	+ -
U5:	Battery capacity	High Low	+ -
U6:	Network capacity	High Low	+ -
U7:	End user security and privacy	High Low	+ -
U8:	Digital Rights Management	Off On	+ -

Firstly the operator policy is either conceived as open or closed. In the open policy firewalls are open and there are no restrictive NAT policies for example. In the closed case on the other hand the operators limit MP2P traffic and different methods to accomplish that have been presented by Tschofenig and Matuszewski (2009). The revenue logic of the operators is either thought to be advertising based or charging based. In the advertising based case operators get revenue from increased flat rate subscriptions and advertising and the service is free for the end user. In the charging based case the operators charge for the usage of MP2P content distribution services. The role of the mobile device as a media device is either primary or supplementary. In the primary case it is assumed that end users are using their mobile device as the primary device for e.g. media management and content consumption. In the supplementary case the personal computer is still the primary media device and mobile device is used as a complementary device. Mobile device capabilities, battery and network capacities as well as end user security and privacy are thought to be either high or low. DRM is a simple binary on / off variable. The correlation matrix constructed from these uncertainties can be seen in Table 10 below. The correlations can be positive (+), negative (-), insignificant (0) or indeterminate (?).

Table 10: Correlations of the uncertainties

	U1	U2	U3	U4	U5	U6	U7	U8
U1	1	+	+	0	0	0	-	?
U2		1	+	0	0	0	-	+
U3			1	+	+	+	+	+
U4				1	+	+	0	0
U5					1	+	0	0
U6						1	0	0
U7							1	+
U8								1

If the operator policy is open the revenue logic of the operators will most likely be advertising based since the charging is difficult for the operator in a bit-pipe role. Also deployment of DRM is more difficult with an open policy, so it is likely to be switched off. Open policy increases the mobile device's role as a media device because there will be more content and services available. The downside of open policy is that it decreases end user security. The correlations of battery capacity, network capacity and mobile device capabilities with operator policy are considered to be insignificant.

If operators charge for the services, security and privacy must be assured. On the other hand charging decreases the media device role of the mobile device, since the services are free in the fixed Internet. The deployment of DRM cannot be determined since it is easier to deploy in closed policy case, but it decreases end user privacy and security as discussed later.

High battery capacity results in high device capabilities and network capacity because more processing power can be achieved with higher battery capacity and thus it can be contributed to the network. The effects of DRM and security and privacy on device capabilities, battery capacity and network capacity are considered to be insignificant.

DRM is assumed to have a positive impact when it is switched off, because it is harmful in terms of privacy since a specific identity may be associated with each use of or access to content. Thus content can not be accessed or used anonymously as is the case with traditional analog media such as books for example. Also security might be reduced when DRM is deployed and involves installation and alteration of software on the end user device (Sohn, 2007).

4.1.5 Forced scenarios

Determining the forced scenarios from the set of key uncertainties is quite straightforward. Table 11 presents the maximum and minimum value scenarios.

Table 11: Forced scenarios

Uncertainty:	**Maximum value scenario:**	**Minimum value scenario:**
Operator policy	Open	Closed
Revenue logic / business model for operators	Advertising	Charging
The role of the mobile device as a media device	Primary	Supplementary
Mobile device capabilities	High	Low
Battery capacity	High	Low
Network capacity	High	Low
End user security and privacy	High	Low
Digital Rights Management	Off	On

The trends T2-T7 can also be attributed to the maximum value scenario and trend T1 to the minimum value scenario.

There are however some inconsistencies in the forced scenarios. If the operator policy is open, end user security and privacy will be low. On the other hand if there is no DRM end user security and privacy will be high. Also trend T1 i.e. that battery capacity will remain a bottleneck may have an impact on the growing mobile device capability trends T2 and T3.

4.1.6 Learning scenarios

We decided to eliminate uncertainty number seven, i.e. end user security and privacy from the learning scenarios because of inconsistency. Also uncertainties five and six were eliminated, because the battery capacity is presumed to stay a bottle neck and network capacity is assumed to stay adequate. According to a Finnish regulator no actions regarding P2P traffic will be taken in the current situation (Tschofenig and Matuszewski, 2008) and thus regulatory intervention is assumed to be minimal in all the scenarios.

Table 12 represents the four developed learning scenarios which were constructed through an iterative process.

Table 12: Learning scenarios

Uncertainty:	Free high-primary	Charged high-secondary	Free low-secondary	Charged low-secondary
Operator policy	Open	Closed	Open	Closed
Revenue logic / business model for operators	Advertising	Charging	Advertising	Charging
The role of the mobile device as a media device	Primary	Supplementary	Supplementary	Supplementary
Mobile device capabilities	High	High	Low	Low
Digital Rights Management	Off	On	Off	On

As defined in the introduction chapter, mobile devices in the scope of this thesis are personal portable laptop computers and personal portable pocket-size computing devices. These devices can’t be thought of as substitutes for each other and thus the mobile device capabilities are determined by the device mainly used for content distribution.

In the *free high-prime* scenario the mobile devices are mainly personal portable laptop computers and thus the device capabilities are high. Because of this, the mobile device is used as a primary media device. The operator policy in this scenario is open and the revenue logic advertising based, because of the difficulties in charging as discussed before. Because of the open policy DRM is also not deployed.

In the *charged high-secondary* scenario mobile devices are mainly still personal portable laptop computers, but because of the closed operator policy and charging based business model there are bound to be less content and services available.

Because of the low amount of content and services and the deployed DRM, the role of the mobile device as a media device will only be supplementary.

Mobile devices are considered to be mainly personal portable pocket-size computing devices in the *free low secondary* scenario and thus have low capabilities. In spite of the open operator policy, advertising based revenue model and non-deployed DRM, the mobile devices are considered to be only supplementary media devices because of the low capabilities. The last two scenarios are similar to each other, but in the *charged low-secondary* scenario the supplementary media device role of the mobile device is further strengthened by the closed operator policy and the charging based business model.

4.1.7 Results

This chapter represented the construction process for the most relevant scenarios regarding MP2P content distribution. The key uncertainties identified were operator policy, operator revenue logic / business model, the role of the mobile device as a media device, mobile device capabilities and Digital Rights Management. These uncertainties were based on expert and layman opinions acquired in the brainstorming sessions and the author's own views acquired through the literature analysis. As a result four learning scenarios were constructed which bound the uncertainty regarding the future of MP2P content distribution.

4.2 System dynamics model

In this chapter a system dynamics model is constructed. The model is based on the scenarios constructed in the previous chapter and follows loosely the modeling process described in chapter 3.2.4. The software used in the modeling is called Vensim PLE (Personal Learning Edition)[25], which is free for educational and personal use and utilized widely in system dynamics modeling. There has not been a lot of research done in the area of P2P and system dynamics. In fact, the author is only aware of one resource based analysis of P2P, where system dynamics is used (Pavlov and Saeed, 2004).

[25] http://www.vensim.com/venple.html [Accessed 19.02.2009]

4.2.1 Background

Usually when building a model to evaluate possible future scenarios, the model has to be first adjusted to fit to historical data. Unfortunately the only data that is available of MP2P that the author is aware of is that there is a growing trend in computer based MP2P file sharing traffic in GSM/UMTS networks in Finland (Heikkinen et al., 2009). To fit to this data the model should be adjusted to deliver similar results.

The second research question was how to turn the scenarios to relevant system dynamic models. Because the decision variable in the scenario process was the value of MP2P content distribution services for the end user, it will be used in the model construction as well. The model will be constructed from a global perspective, i.e. the average value of MP2P content distribution services for the end user is considered. If a user contributes large amounts of content to the network, the individual value of the network for this particular user decreases. This individual perspective is, however, disregarded and thus the overall value of the network is assumed to increase when users contribute content to it. The time horizon for the model is 2009-2013 as defined by the scope of the thesis.

4.2.2 Assumptions and data

This chapter presents the subjective assumptions made by the modeler and the data that was used in the quantitative modeling. All the parameters and equations that construct the model and are described in this chapter can be found in the appendix *Formulas*.

Adoption

Sterman (2000) has identified four channels which can stimulate adoption of new innovations, namely advertising, media reports, direct sales efforts and word-of-mouth. In this model only word-of-mouth is assumed to have an impact on the adoption. Thus there are no advertising parties or other external factors and a small end user base is assumed to have been established. To model the influence of word-of-mouth, a modified Sterman's (2000) version of the Bass diffusion model (Bass, 1969) is used. Word-of-mouth is only assumed to have an effect on the adoption rate of new end users – the end users base their decisions to departure solely on content attractiveness. Content attractiveness is determined by the user's contributed content vs. available content per user in the network with the amount of DRM-content also affecting the attractiveness. The departure rate and adoption rate behave linearly in relation to content attractiveness. The model also assumes that once an end user departs from the system, he or she can not adopt it again. The users who are using *Fishing*, i.e. logging into the system, downloading what they need and leaving the system directly are not considered to be users who depart from the system, but rather passive end users who are free riding.

Variable *Contact Rate* in the Bass model refers to the amount of contacts an adopter has with potential users in a certain time period. *Adoption Fraction* on the other hand refers to the fraction of potential users that adopt the innovation when contacted by an adopter. The values used in this model are 0.015 for adoption fraction and 100 for contact rate per year. Similar values have been used for example in simulating mobile phone usage (Wang and Cheong, 2006) and sales of computers (Sterman, 2000).

According to the Finnish Copyright Information & Anti-Piracy Centre[26] (CIAPC) there were approximately one million broadband users and estimated 150000 active P2P users in Finland in 2005. If we assume that this ratio of 15% remains constant, we can conclude that from the 300,000 mobile broadband users in Finland (Ficora, 2008) about 45,000 are potential MP2P users in the beginning of the simulation. When comparing these figures to Sweden, a neighboring country to Finland, the results are similar. There were approximately 700,000 P2P users in Sweden in the beginning of 2008[27] and about 4M Internet access customers (PTS, 2008), yielding a ratio of 18%.

The amount of mobile broadband subscriptions in Finland has more than doubled in the last six months (Ficora, 2008) and it is hard to estimate what the growth will be in the coming years since mobile broadband is still in its early phase in Finland. In the model it is assumed that the amount of mobile broadband subscriptions and thus new potential end users for MP2P will double during the first year of simulation, rise 50% during the next year and after that 10% less annually until year 2013. This imitates

[26] http://www.antipiracy.fi/inenglish/ [Accessed 10.12.2008]

[27] http://tech.yahoo.com/news/afp/20081217/tc_afp/swedeninternetcrimecopyright_081217170334 [Accessed 22.12.2008]

loosely the rise in the amount of fixed broadband connections in Finland during the years 2002 – 2006[28]. The total population of Finland is 5,300,000 and it is assumed to stay constant in the scope of this model.

Content

In this model content will be the only resource distributed – the effects of bandwidth, processing power and storage are excluded. Also streaming and commercial P2P systems are excluded and only file sharing considered. The typical amount of files shared per laptop user is assumed to be 100 files. Saroui et al. (2002) have measured that 75 % of the peers in the Gnutella network and approximately 90 % of the peers in the Napster network shared less than a hundred files, so this is a justified assumption since the majority of the shared content is contributed by the minority of the peers. The handset users on the other hand are assumed to share 10 files typically. The influences of third party content providers are excluded and only end users are contributing content to the network. Although MP2P applications like Symella and SymTorrent are connected to the fixed networks of Gnutella and BitTorrent respectively, it is assumed in this model that the MP2P network is independent from the fixed network and content to the MP2P network is only contributed by the mobile users.

The minimum Free Riding fraction in the model is assumed to be 0.09 based on the research conducted by Pavlov and Saeed (2004). The maximum Free Riding ratio is assumed to be 0.85 based on the measurement on Free Riding by Hughes et al (2005). According to Adar and Huberman (2000) the Free Riding ratio of a P2P network of about 33,000 peers was 66 %. Considering that Free Riding increases with the group size (Isaac and Walker, 1988), a lookup function for Free Riding is constructed based on these assumptions. The lookup function is S-shaped, because it is assumed that the early adopters are less likely to free ride than the users joining the network later on. It is also assumed that the users are unaware of Free Riding and thus it does not affect their content contribution.

[28] http://www.stat.fi/til/tvie/2007/tvie_2007_2008-06-05_tau_004_fi.html [Accessed 02.01.2008]

Operator policy

Regarding the operator policy it is assumed that the operators start to limit P2P traffic after a certain level of traffic is exceeded. Some operators have already deployed this in fixed networks and similar problems are also expected in the mobile networks (Tschofenig and Matuszewski, 2009). In the scenario construction process it was also considered that limited flat rate will be the dominant pricing model in mobile networks which further reinforces the assumption made in this model.

The implementation of operator policy in the model is very simple. It is assumed that the operators have designed the network for a certain amount of traffic and once this amount is exceeded the operators start to limit traffic. Traffic is not modeled as a separate variable but instead it is assumed that once the allowed amount of users (and the traffic they generate) is exceeded, operators start to limit traffic and the contributed content in the system decreases.

Device capabilities

The device capabilities are modeled by means of the device base. The devices are divided to laptops and handsets, and the capabilities can be altered by changing the variable “Share of handsets”.

Kivi (2009) has measured the percentages of mobile handsets and data terminals (data cards, USB modems, embedded data modules) used in the Finnish mobile networks. The share of data terminals has grown steadily during 2005-2008 and especially since fall 2007. In 2008 the share of data terminals was 4.9 percent and from the 95.1% share of mobile handsets 21 percent were based on *Symbian*[29] platform and are thus considered capable of using MP2P applications. Thus we can conclude that one fifth of the mobile devices capable of using MP2P are laptops and the rest handsets in the beginning of the simulation.

Digital Rights Management

As defined in the scenario construction process DRM is assumed to have a negative effect on the end users. The modeling of DRM in this model is fairly straightforward

[29] http://www.symbian.com/index.asp [Accessed 26.1.2009]

– the bigger the share of DRM content in the network is, the less attractive the content becomes. This reduces the amount of end users and available content in the system. One could also think of a superdistribution system, where users might have a financial or social incentive to share DRM content and thus content attraction would increase the more there is DRM content in the system, but in this case such a scenario is excluded.

4.2.3 Conceptual model

Figure 21 below shows the conceptual model of the system which only sketches the causal connections between the variables and has no functionality.

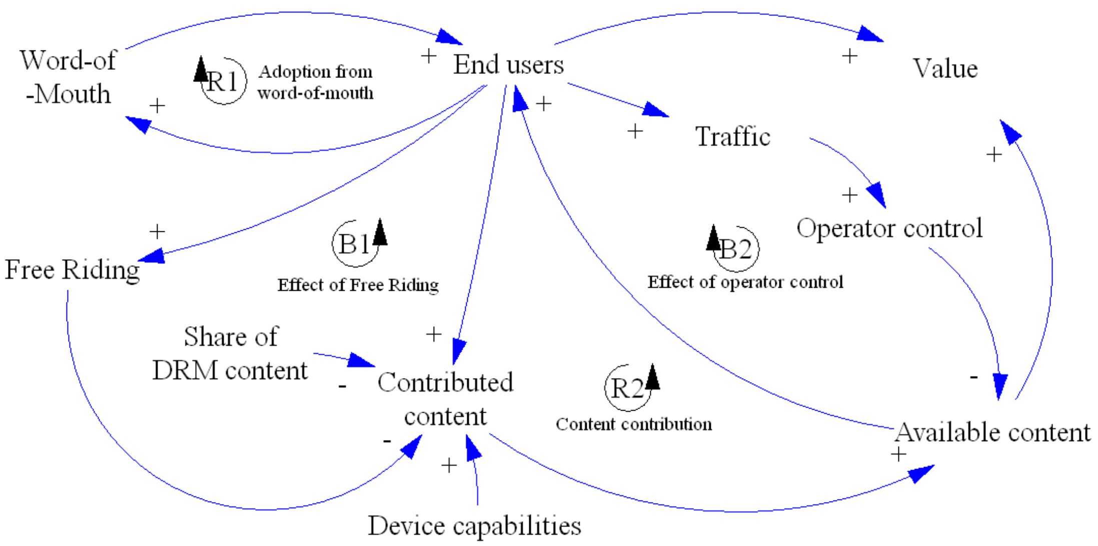

Figure 21: Conceptual model

There are four feedback loops in the system - two of which are reinforcing and the other two balancing loops. The first reinforcing loop (R1) describes the adoption from word-of-mouth. The more end users there are the bigger the effect of word-of-mouth becomes and thus new users adopt the technology. The second reinforcing loop (R2) depicts the content contributed by the end users. The more end users there are, the more there is available content in the system, which in turn attracts more end users. Without balancing loops the amount of end users would just grow exponentially. Thus the first balancing loop (B1) is needed to describe the effect that Free Riding has on contributed content. The more end users there are, the bigger the Free Riding ratio becomes. This naturally decreases the amount of contributed content and thus there is less content available in the system. When the amount of available content decreases the amount of end users does the same. The second balancing loop (B2) depicts the effect of operator control. As the amount of end users grows, the amount of traffic grows as well. When the amount of traffic reaches a certain limit operators start to restrict the traffic and thus there is less available content in the system.

The share of DRM content and the device capabilities are not part of any loops; they are just variables affecting the contributed content. As already mentioned DRM has a negative effect on end users and makes them contribute less content. The device capabilities on the other hand naturally increase the contributed content because of the better user interface, battery duration, memory and processing power. The variable value is only used to describe the product of available content and end users as it was the decision variable in the scenario construction process.

4.2.4 Scenarios and the model

The latter of the research questions of this thesis was how to turn the scenarios into relevant system dynamic models. This turned out to be a very challenging task, mainly because of the nature of the scenarios and many abstract variables, for example the device role as a media device, which were difficult to model quantitatively.

Instead of trying to get quantitative results of these scenarios the focus developed to modeling the dynamic behavior of the system, i.e. the effects of the different variables on the value of MP2P content distribution. Simulating the model shows the effects that the different variables have on the amount of users and content in the system, i.e. the value of the system. Different simulations describing the dynamic behavior of the system are depicted in the next chapter.

4.2.5 Quantitative model

The quantitative model is constructed based on the assumptions, available data and the conceptual model and it can be seen in Figure 22. The base of the model consists of two coflows – the other one depicting the flow of persons from potential end users to end users and the other one the flow of content in the system. The two stock variables “End users” and “Available content” together constitute the variable “Value”.

The number of potential users grows as new mobile broadband subscriptions emerge. These potential users adopt the technology by a rate defined by the Bass model and content attractiveness and departure when the content becomes non-attractive to them. As the users departure they take a certain amount of content away with them. The amount of content is also affected by Free Riding and the share of DRM content and possibly also by operator control if deployed. The contributed content is divided to content contributed by handset and laptop users, which contribute their respective amounts of files to the system.

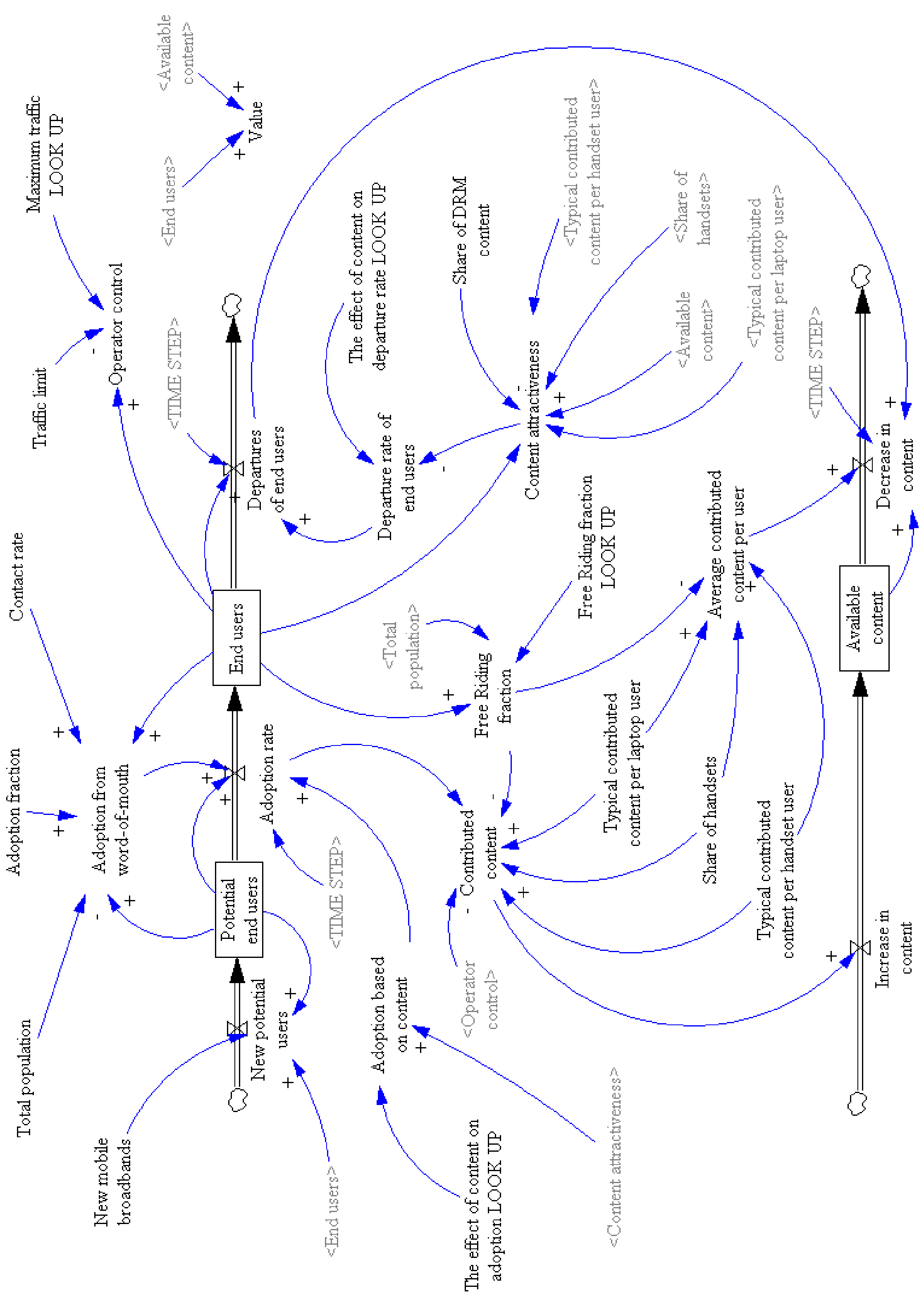

Figure 22: Quantitative model

Dynamic behavior of the model

Simulating the model clearly shows the dynamic behavior of the model. When simulating the model with the initial values, the increase in the amount of end users is quite insignificant (Figure 23). This is mainly because of the small initial user base in relation to total population, which results in minor adoption from word-of-mouth. Regarding the growing trend in computer based MP2P file sharing traffic in GSM/UMTS networks in Finland observed by Heikkinen et al. (2009), the model seems to behave accordingly.

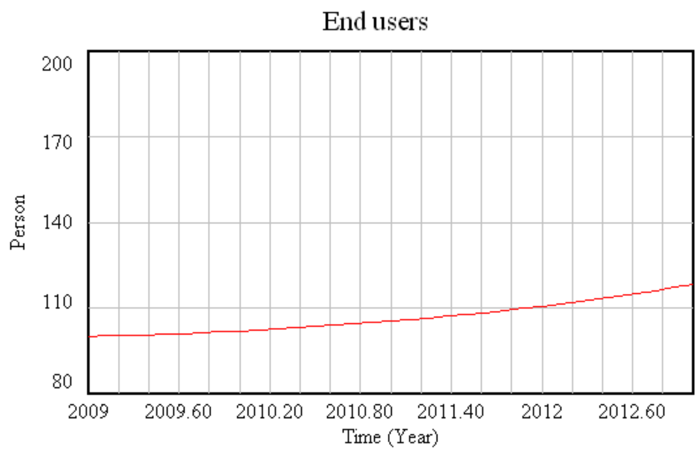

Figure 23: The amount of end users simulated with initial values

The x-axis of the figure is not represented in whole years because of the time step used in the simulation. The years are represented in fractions, which means that the 2010.20 point of time is the 73rd day of the year 2010 for example.

As the adoption rate is increased with a larger values for adoption fraction and contact rate, the effects of the increased user base on the dimensionless (Dmnl) Free Riding fraction (Figure 24) can clearly be seen.

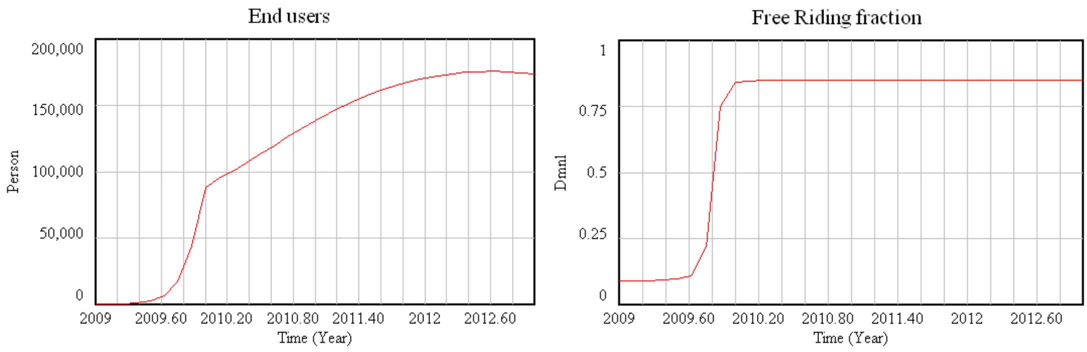

Figure 24: The effect of end users on Free Riding

As the Free Riding fraction increases the departure rate of users begins to grow as well (Figure 25a). The increase in departure of end users affects directly as decrease in content (Figure 25b).

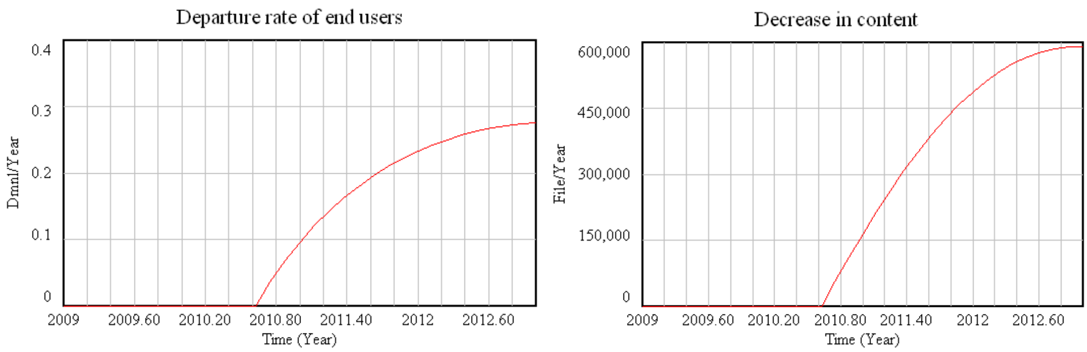

Figure 25: Departure rate of end users (a) and its effect on content (b)

The increased user base (and traffic resulting from it) also results in operator control if it is deployed (Figure 26a), which together with Free Riding decrease the contributed content by the users (Figure 26b).

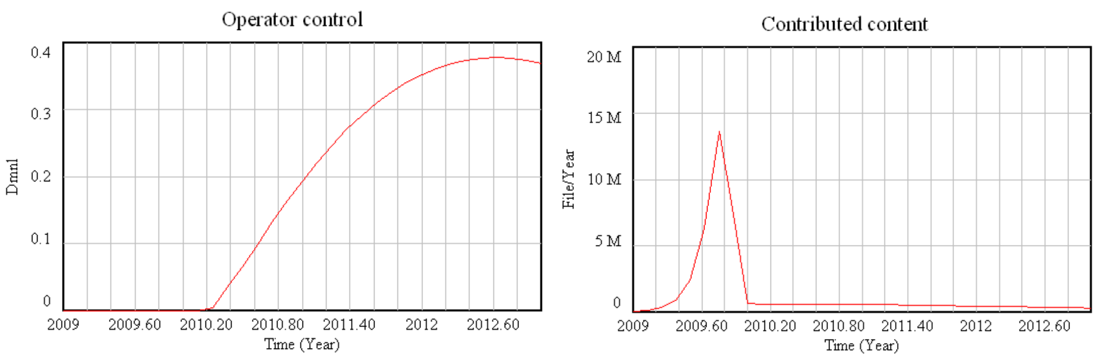

Figure 26: Operator control (a) and its effect on contributed content (b)

Available content (Figure 27a) in the system behaves in a similar manner to the user base, as they directly affect each other because of the coflow structure. The value in the model was modeled as the product of end users and available content and can be seen in Figure 27b.

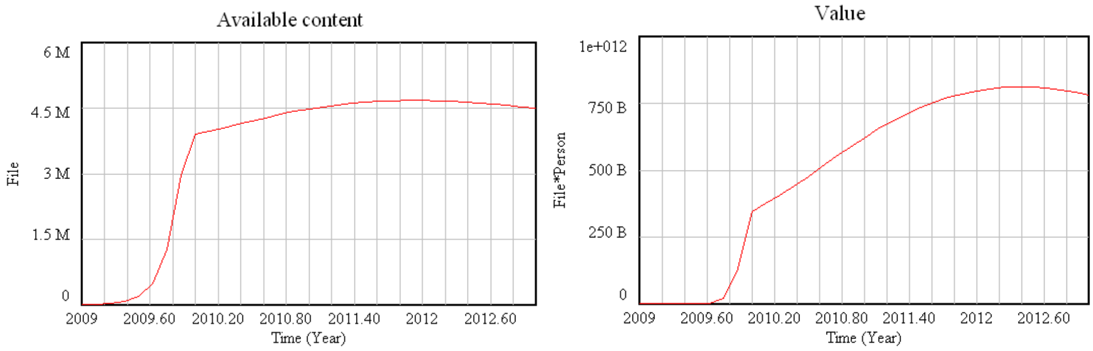

Figure 27: Available content in the system (a) and value (b)

In the simulation figures above the share of DRM content was zero, so increasing the share of DRM content would even further reduce the amount of content in the system and thus also the amount of end users and value. The share of handsets in the simulations was kept constant in 20 %. One might think that the more laptops there are the more content there also is, because the laptops contribute more content than the handsets. This is, however, not the case in this model, because of the characteristics of content attractiveness. Content in this model is the most attractive to the users when there are the same amount of laptops and handsets (i.e. 50 % each) in the system. This is because the content attractiveness is not the same for handset and laptop users. The users compare the available content to their respective amounts of contributed content depending on what device they are using. Thus the handset users see the system as very attractive when there are many laptop users, but on the other hand the more handset users there are the less attractive the content becomes for the laptop users. Thus the content is the most attractive to all the users on average when there is the same amount of laptop and handset users. If it is assumed that the laptop users always contribute more content than the handset users, the more laptop users there are the more attractive the content becomes for an average user. This is because the effect of increased available content in the system is bigger than the effect of increased contributed content for an average user and thus content attractiveness increases. On the other hand, increasing the contributed content of handset users decreases the content attractiveness for an average user, because the increase in available content in the system is smaller than the increase in contributed content for an average user and thus content attractiveness decreases.

4.2.6 Results and limitations

First a conceptual model was constructed in this chapter to model the causal connections between different variables regarding the MP2P content distribution system based on the scenarios. This conceptual model provides an overview of the system and has no functionality. The functionality was included in the quantitative model, which was supposed to model the scenarios quantitatively. The quantitative modeling of the scenarios proved to be a very challenging task and thus it was decided that the dynamic behavior of the system would only be modeled. The model is naturally a rough simplification of the real world and it for example excludes the possibility of massive amounts of new end users adopting the technology suddenly as happened with *Napster* for instance, where the user base was doubling every five to six weeks after the release in 1999[30]. The development of MP2P in this model is constant and new users adopt MP2P at the rate defined by the Bass model and content attractiveness.

The assumptions made during the model construction process are always subjective views of the author and have to be approached accordingly. The modeler's skills were also limited, this model being the first model of the author ever built. Using a method as complex as system dynamics usually requires a lot of practice and experience. The skills are needed to derive feasible quantitative results and thus the decision by the author just to model the dynamic behavior of the system seems justified. The model, however, has to be used with consideration also regarding the dynamic behavior of the scenarios as the effects of DRM, operator policy and device capabilities are totally subjective.

Sterman (2000) has stated that validation and verification of a model are impossible and one should concentrate on the usefulness of a model rather than trying to validate or verify it. Sterman has also presented a list of tests for the assessment of dynamic

[30] http://www.newsweek.com/id/84996/page/2 [Accessed 08.01.2009]

models. Regarding these tests the model constructed in this thesis behaves robustly and has no surprise behavior even in extreme conditions. The dynamic behavior of the system is not sensitive to the choice of time step and the parameter values and dimensions are consistent and validated with the *units check* function of the Vensim software. The coflow structure of the model also corresponds well to a real world P2P system. These things in mind and regardless of the limitations, the model in this thesis can be seen as a useful tool in modeling the dynamic behavior of the system in question.

5 Conclusions

This chapter concludes the thesis by presenting the major findings of the thesis and their reliability and validity. Analysis and discussion is also performed in order to get an understanding of what the results really mean, how they are related to previous research, what the limitations, advantages and applications of the results might be and what could be researched in the future.

5.1 Results

The first research question of this thesis was about finding the most relevant scenarios regarding MP2P content distribution. Thus one of the major results of this thesis is the construction of these scenarios presented in Chapter 4.1. The most important uncertainties regarding the future of MP2P content distribution proved to be operator policy, operator’s revenue logic and business model, the role of the mobile device as a media device, mobile device capabilities and Digital Rights Management. These uncertainties and their different outcomes construct the learning scenarios that were developed as a result of the scenario construction process. The scenario construction process followed tightly Schoemaker’s method introduced in Chapter 3.1 and thus the process can be construed as valid. The scenarios, however, are always the author’s own views and assumptions to an extent and have to be treated with deliberation. Because of this and to support the author’s own views an extensive literature study and brainstorming sessions were used to validate the scenarios. The scenarios bound the uncertainty regarding the future of MP2P content distribution. Whether these scenarios in particular are the most important ones and match the reality in the future, remains to be seen.

The modeling process regarding the second research question, i.e. the system dynamics modeling of the scenarios, turned out to be a very challenging task. The idea was to construct relevant quantitative models based on the scenarios, but during the modeling process the focus developed to modeling the dynamic behavior that the different variables constructing the scenarios have on an MP2P content distribution system. The model is a rough simplification of a real system and excludes many factors, but the dynamic behavior of the system can be feasibly portrayed with it. However, too thorough conclusions should not be made from the model, as the quantitative modeling of some abstract variables and interactions between them were based on the modeler’s subjective views.

These two results construct the main results of the thesis as they answer the research questions described in the beginning of the thesis. The reliability and validity of the results have been maximized by using expert opinions and Sterman’s (2000) tests for dynamic model assessments for instance, but up to a point the results are the author’s own subjective views and have to be treated accordingly. The objectives of the research, i.e. understanding the most relevant scenarios, stakeholders and their incentives related to MP2P content distribution and building a system dynamic model based on the scenarios were achieved, although it is not feasible to draw quantitative results from the model.

5.2 Analysis and discussion

Other previous scenario analysis research performed in the area of MP2P has included MP2P service usage and mobile P2PSIP for example. The research conducted in this thesis is the first public scenario analysis conducted specifically of MP2P content distribution that the author is aware of. This lays a foundation for further scenario research in this area. The system dynamics modeling performed is also the first public quantitative model in the area of MP2P that the author is aware of and is by no means a sufficient representation of the topic. As with the scenario analysis, the modeling in this thesis works as a good starting point for further quantitative modeling.

In spite of the difficulties in modeling some of the variables quantitatively system dynamics proved to be a usable tool in modeling systems as the one in this thesis. To derive relevant results from the model is another issue; each case has its own characteristics and it has to be case-specifically evaluated whether system dynamics should be used or not. All in all system dynamics provides an alternative to more common modeling techniques such as spreadsheet modeling, with a distinctive benefit of modeling the feedback loops in a system when used proficiently.

5.3 Further research

One of the biggest challenges in the system dynamics modeling process in this thesis was the amount of abstract variables and unavailable data. MP2P as a technology is still in its infancy and thus better quantitative modeling could be performed in the future, when data becomes available. More alternative quantitative models could also be constructed, for example for MP2P streaming or commercial systems to get a better overview of the topic. The modeling in this thesis was performed from the end user perspective and thus the future models could be constructed from a content provider's or operator's perspective for example. Different MP2P content distribution scenarios could also be built, possibly with less abstract variables resulting in easier system dynamics modeling of the scenarios.

System dynamics requires a thorough understanding of the topic in question and also of system dynamics as a method to derive relevant quantitative results. Thus using an experienced system dynamics modeler in the quantitative modeling of MP2P content distribution is encouraged in the future.

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Appendix

Formulas

(01) Adoption based on content=
The effect of content on adoption LOOK UP(Content attractiveness)
Units: Dmnl

(02) Adoption fraction=
0.015
Units: Dmnl [0,1,0.01]

(03) "Adoption from word-of-mouth"=
(Contact rate*Adoption fraction*Potential end users*End users)/Total population
Units: Person/Year

(04) Adoption rate=
MIN(Adoption based on content*"Adoption from word-of-mouth", Potential end users/TIME STEP)
Units: Person/Year

(05) Available content= INTEG (
Increase in content-Decrease in content, Initial available content)
Units: File [0,?]

(06) Average contributed content per user=
(1-Free Riding fraction)*((1-Share of handsets)*Typical contributed content per laptop user+Share of handsets*Typical contributed content per handset user)
Units: File/Person

(07) Contact rate=
100
Units: Dmnl/Year [0,1000]

(08) Content attractiveness=
(1-Share of DRM content)*((Share of handsets*Available content/End users)/Typical contributed content per handset user+((1-Share of handsets)*Available content/End users)/Typical contributed content per laptop user)
Units: Dmnl

(09) Contributed content=
(1-Operator control)*(1-Free Riding fraction)*Adoption rate*(Share of handsets*Typical contributed content per handset user
+(1-Share of handsets)*Typical contributed content per laptop user)
Units: File/Year

(10) Decrease in content=
MIN(Average contributed content per user*Departures of end users, Available content/TIME STEP)
Units: File/Year

(11) Departure rate of end users=
The effect of content on departure rate LOOK UP(Content attractiveness)
Units: Dmnl/Year

(12) Departures of end users=
MIN(Departure rate of end users*End users, End users/TIME STEP)
Units: Person/Year

(13) End users= INTEG (
Adoption rate-Departures of end users, Initial end users)
Units: Person [0,?]

(14) FINAL TIME = 2013
Units: Year
The final time for the simulation.

(15) Free Riding fraction=
Free Riding fraction LOOK UP(End users/Total population)
Units: Dmnl [0,1,0.01]

(16) Free Riding fraction LOOK UP(
[(0,0)-(0.02,1)],(0,0.09),(0.001154,0.105263),(0.00253881,0.153509),(0.00369281,0.254386),(0.00444291,0.368421),(0.00490451,0.460526),(0.00542381,0.565789),(0.00622641,0.66),(0.0074433,0.723684),(0.00877041,0.763158),(0.010386,0.798246),(0.0118285,0.815789),(0.0132133,0.828947),(0.0148289,0.837719),(0.0168484,0.842105),(0.0188679,0.85))
Units: Dmnl

(17) Increase in content=
Contributed content
Units: File/Year

(18) Initial available content=
Initial end users*Average contributed content per user
Units: File

(19) Initial end users=
100
Units: Person [0,1000,10]

(20) Initial potential end users=
Potential MP2P end users in Finland-Initial end users
Units: Person [0,?,1000]

(21) INITIAL TIME = 2009
Units: Year
The initial time for the simulation.

(22) Maximum traffic LOOK UP(
[(0,0)-(3,1)],(0,0),(1,0),(2,0.5),(3,1))
Units: Dmnl

(23) New mobile broadbands
Units: Dmnl/Year

(24) New potential users=
New mobile broadbands*(Potential end users+End users)
Units: Person/Year

(25) Operator control=
Maximum traffic LOOK UP(End users/Traffic limit)
Units: Dmnl

(26) Potential end users= INTEG (
New potential users-Adoption rate, Initial potential end users)
Units: Person

(27) Potential MP2P end users in Finland=
45000
Units: Person

(28) SAVEPER =
TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

(29) Share of DRM content=
0
Units: Dmnl [0,1,0.1]

(30) Share of handsets=
0.2
Units: Dmnl [0,1,0.1]

(31) The effect of content on adoption LOOK UP(
[(0,0)-(1,1)],(0,0),(1,1))
Units: Dmnl

(32) The effect of content on departure rate LOOK UP(
[(0,0)-(1,1)],(0,1),(1,0))
Units: Dmnl/Year

(33) TIME STEP==
0.125
Units: Year [0,?]
The time step for the simulation.

(34) Total population==
5.3e+006
Units: Person [0,?]

(35) Traffic limit=
100000
Units: Person [0,1e+006,1000]

(36) Typical contributed content per handset user=
10
Units: File/Person

(37) Typical contributed content per laptop user=
100
Units: File/Person

(38) Value=
End users*Available content
Units: Person*File